**KHARKOV NATIONAL MEDICAL UNIVERSITY**
**Physiology department**

# WORKBOOK

FOR INDIVIDUAL STUDENTS` WORK

## PHYSIOLOGY OF VISCERAL SYSTEMS
## «BLOOD, CIRCULATION AND RESPIRATION»

Name_____

Faculty_____

Group_____ course_____

2020

**МІНІСТЕРСТВО ОХОРОНИ ЗДОРОВ'Я УКРАЇНИ**
**Харківський національний медичний університет**

# Physiology of Visceral Systems «Blood, Circulation and Respiration»

## *Manual for individual work of second-year students (English-medium)*

# Фізіологія крові, кровообігу та дихання

## *Методичні вказівки для самостійної роботи студентів 2-го курсу з англомовною формою навчання*

Затверджено Вченою радою ХНМУ.
Протокол № 12 від 17.12.2020.

**Харків**
**ХНМУ**
**2020**

Physiology of visceral systems Blood, circulation and respiration" : manual for individual work of second-year students (English-medium) / comp. L. V. Chernobay, D. I. Marakushin, I. N. Isaeva et al. – Kharkov : KhNMU, 2020. – 104 p.

Compilers L.V. Chernobay
D.I. Marakushin
I.N. Isaeva
I. S. Karmazina
R. V. Alexeenko
N. S. Hloba
O. V. Vasylieva,
O. D. Bulynina,
M. P. Kyrychenko,
O. V. Dynaeva,
A. V. Honcharova,
S. V. Shenger

Фізіологія вісцеральних систем «Кров, кровообіг, дихання» : методичні вказівки для самостійної роботи студентів з англомовною формою навчання / упоряд. Л. В. Чернобай, Д. І. Маракушин, І. М. Ісаєва та ін. – Харків : ХНМУ, 2020. – 104 с.

Упорядники Л. В. Чернобай
Д. І. Маракушин
І. М. Ісаєва
І. С. Кармазіна
Р. В. Алексеєнко
О. В. Васильєва,
Н. С. Глоба
О. Д. Булиніна
М. П. Кириченко
О. В. Дунаєва,
А. В.Гончарова,
С. В. Шенгер

## Introduction

The blood, heart and blood vessels constitute the circulatory system and provide a link between the bodies' internal compartments and external environment. More specifically, the blood transports nutrients from gastro-intestinal tract to cells, oxygen from respiratory system to cells, wastes from cells to excretory organs; it carries hormones from endocrine glands to target cells and aids in body thermoregulation. Thus, the blood provides vital support for cellular activities and participates in maintaining a favorable cellular environment. However, all these functions of blood are possible just in case of normal physiological state of heart and closed system of vessels that move blood throughout the body.

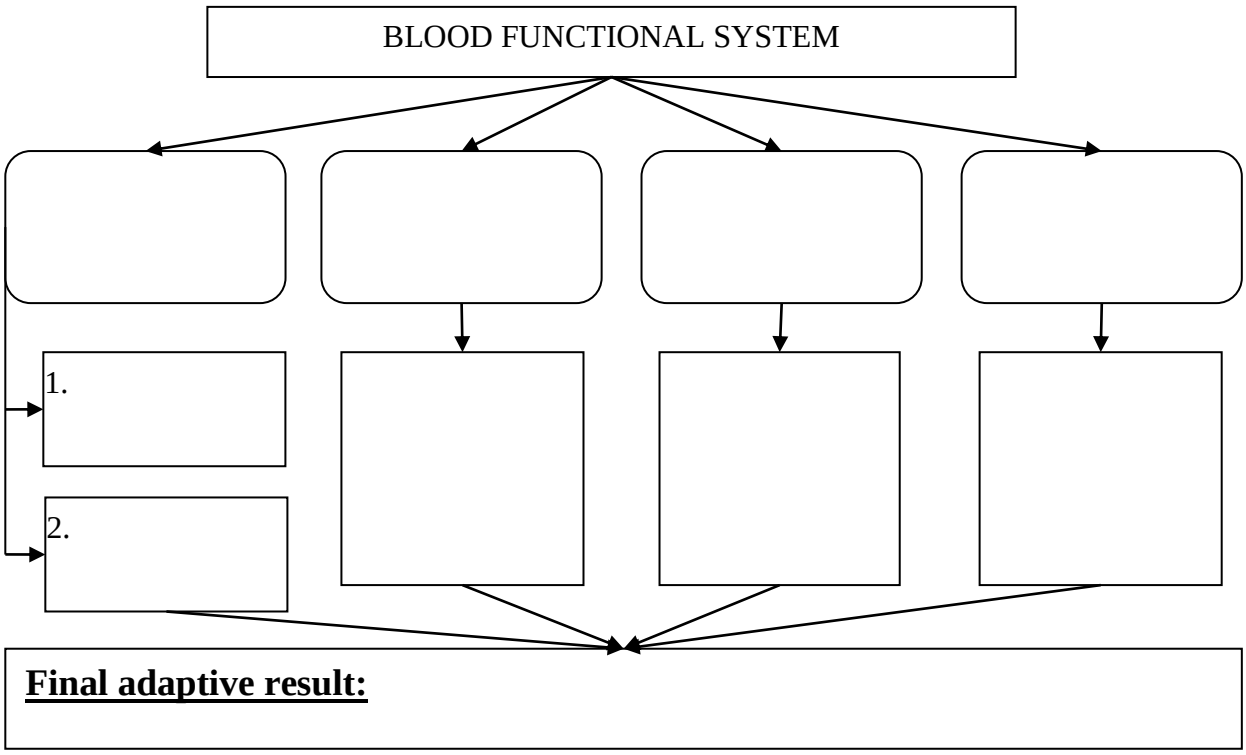
We hope that this workbook will help you to understand physiology of blood and circulation system and to acquire good knowledge for your future medical education and practice.

Good luck!

# PHYSIOLOGY OF BLOOD SYSTEM

## 1. Functions and composition of blood. Physical and chemical properties of blood.

**Task 1.1.** *Complete the scheme of the blood functional system structure.*




**Task 1.2.** *Give definition of blood.*

_____

_____

_____

**Task 1.3.** *Functions of the blood are*:

1._____

_____

2._____

_____

3._____

_____

4._____

_____

5._____

_____

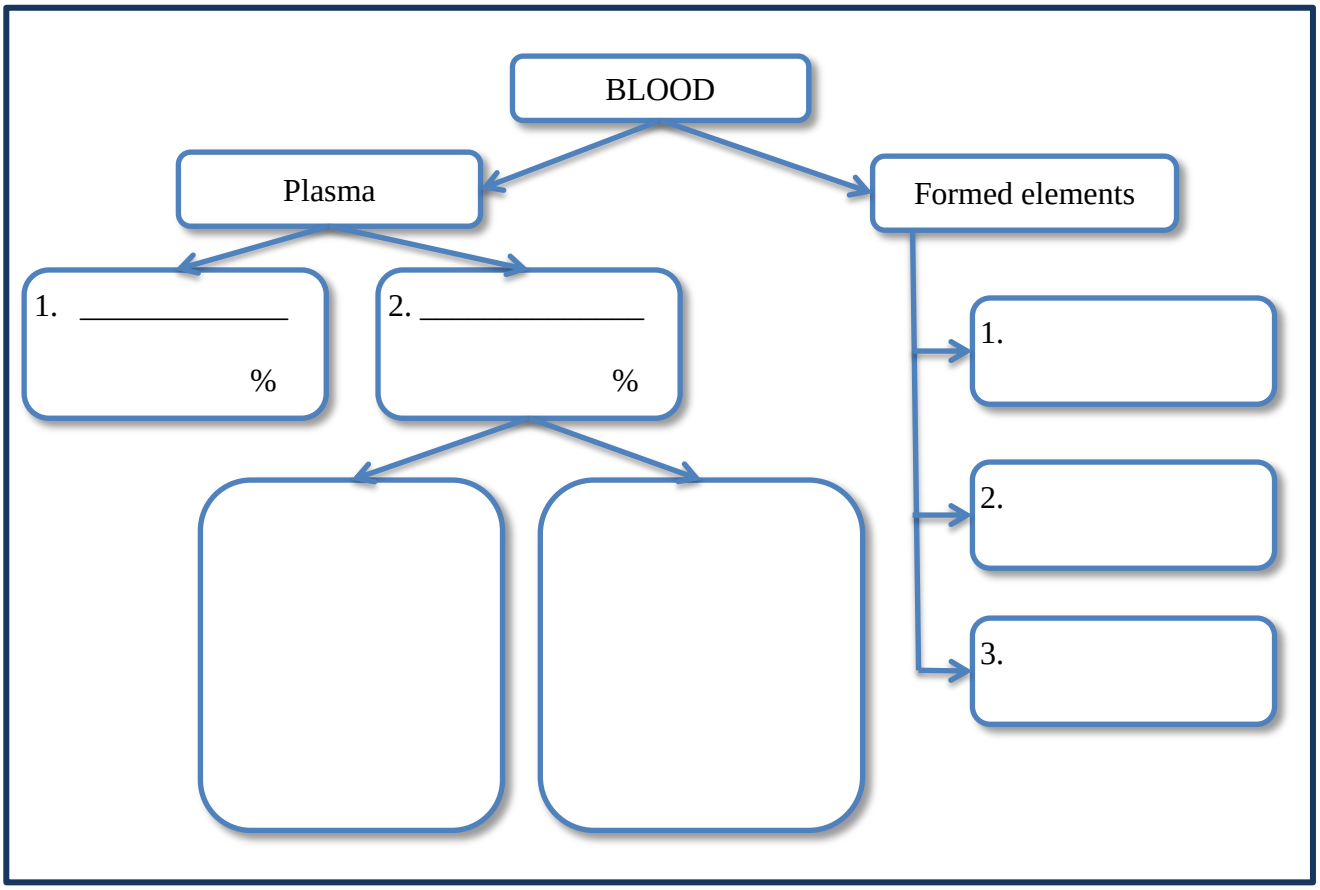
6._____

_____

7._____

_____

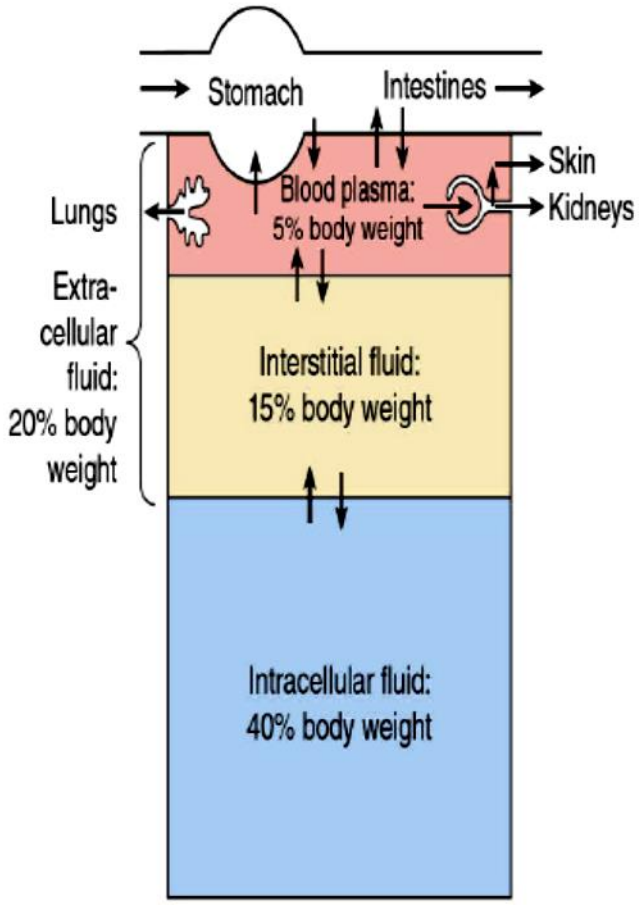
**Task 1.4.** *Define the blood composition and content of its components.*




**Task 1.5.**

| № | parameter | description |
|---|---|---|
| 1 | Volume | |
| 2 | Temperature | |
| 3 | pH | |
| 4 | Viscosity | |
| 5 | Osmotic pressure | |
| 6 | Oncotic pressure | |
| 7 | Relative density | |

**Task 1.6. Total body water. Complete the sentences.**




Intracellular fluid (ICF): approximately _____of total body water

Extracellular fluid (ECF): approximately _____ of total body water

Interstitial fluid (ISF): approximately _____ of the extracellular fluid

Plasma volume (PV): approximately _____ of the extracellular fluid

Vascular compartment: _____

**Task 1.7. Give definition of following terminology.**

**1. NORMOVOLEMIA –**

_____

_____

**2. HYPOVOLEMIA –**

_____

_____

**3. HYPERVOLEMIA –**

_____

_____

**Task 1.8. Define Hematologic laboratory normal values for males and females**

| № | parameter | Normal values |
|---|---|---|
| **1** | **Erythrocyte count** | |
| **2** | **ESR** | |
| **3** | **Hematocrit** | |
| **4** | **Hemoglobin** | |
| **5** | **Reticulocyte count** | |
| **6** | **Platelet count** | |

**Task 1.9. Define Hematologic laboratory normal values for Leukocyte count and differential**

| № | parameter | Normal values |
|---|---|---|
| **1** | Leukocyte count | |
| **2** | Segmented Neutrophils | |
| **3** | bands | |
| **4** | Eosinophils | |
| **5** | Basophils | |
| **6** | Lymphocytes | |
| **7** | Monocytes | |
| **N**eutrophils **L**ike **M**aking **E**verything **B**etter | | |

## OSMOLARITY AND OSMOTIC PRESSURE

**Task 1.10. Give definition of the following terminology:**

1. **Osmosis**

   _____
   _____

2. **Osmotic pressure**

   _____
   _____

3. **Osmolarity**

   _____
   _____

4. **Osmolality**

   _____
   _____

| Parameter | Normal values |
|---|---|
| Osmotic pressure | |
| Osmolarity | |

**Task 1.11. Hematologic laboratory normal values for osmotic substances. Fill in the table**

| INDEX | SI reference intervals |
|---|---|
| osmolality | |
| Sodium | |
| Potassium | |
| Calcium | |
| Magnesium | |
| Bicarbonate | |
| Chloride | |
| Glucose | |

**Task 1.12. Use the following formula to calculate plasma osmolarity and make conclusion.**

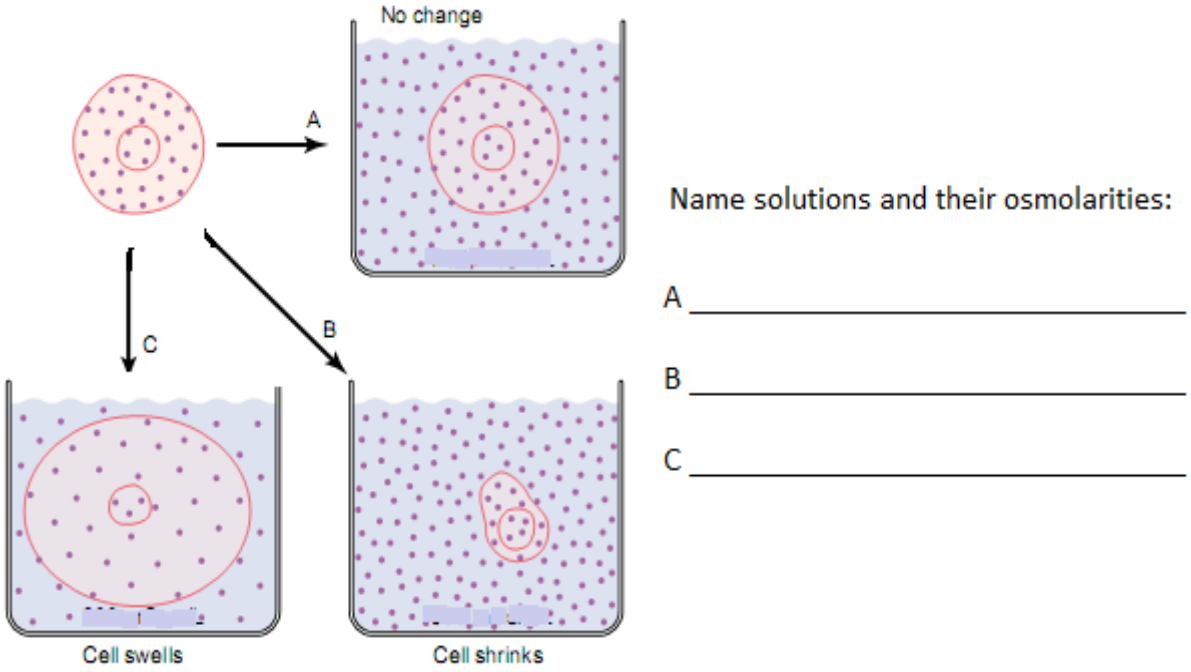
**$2(Na^+ + K^+)$ + Glucose (mg%) / 18 + Urea (mg%) / 6 = _____**

- ✓ if Plasma $Na^+$ – 135 mEq /l ,
- ✓ Plasma $K^+$ – 5 mEq / l,
- ✓ Plasma glucose – 90 mg% (dL)
- ✓ and blood Urea – 30 mg% (dL)

**Task 1.13. Name the types of solution according to osmotic pressure.**

1. Solutions that have the same tonicity as plasma are said to be _____;
2. _____ and _____ refer to higher or lower tonicities as plasma, respectively.
3. All solutions that are initially isosmotic with plasma would remain isotonic if it were not for the fact that some solutes diffuse across cell membranes and others are metabolized (without being metabolized and diffused).
4. Thus, a _____ solution of NaCl remains isotonic because there is no net movement of the osmotically active particles in the solution into cells and the particles are not metabolized.
5. A _____ glucose solution is isotonic when initially infused intravenously, but glucose can move across the plasma membrane, and can be metabolized, so the net effect is that of infusing a hypotonic solution.

**Task 1.14.** *Define the osmotic resistance of RBC.*



**Task 1.15. There are 3 important hormones involved in volume regulation: aldosterone, ADH and ANP. Fill in the table.**

| Hormone | Endocrine gland (cells) | Stimulus to release hormone | Function |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

## Plasma proteins

**Task 1.16. Fill in the table.**

| Protein | Molecular weight | Concentration (g/L) | Function |
|---|---|---|---|
| **Albumin** | | | |
| **Globulins** | | | |
| **α1-Globulin** | | | |
| **α2-Globulins** | | | |
| **β-Globulins** | | | |
| **¥-Globulins** | | | |
| **Fibrinogen** | | | |

**Task 1.17. Fill in the table.**

| Function | Description |
|---|---|
| **Protein Nutrition** | |
| **Colloid Osmotic Pressure and water balance** | |
| **Buffering action** | |
| **Blood Coagulation** | |
| **Viscosity** | |
| **Transport of substances** | |
| **Immunity** | |

**Task 1.18.** *Define the oncotic pressure of blood and its value.*

_____

_____

_____

Fluid movement across a capillary wall is driven by the Starling pressures across the wall and is described by the **Starling equation** which states that *fluid movement (Jv) across a capillary wall is determined by the net pressure across the wall, which is the sum of hydrostatic pressure and oncotic pressures*

$$J_v = K_f[(P_c - P_i) - (\pi_c - \pi_i)]$$

***The direction of fluid movement can be either into or out of the capillary.***

1. When net fluid movement is *out of* the capillary into the interstitial fluid, it is called **filtration;**
2. When net fluid movement is from the interstitium *into* the capillary, it is called **reabsorption πc, capillary oncotic pressure,** is a force opposing filtration, it is determined by the **protein concentration** of capillary blood.

**Therefore,** ***increases in protein concentration of blood cause increases in πc and decrease filtration, and decreases in protein concentration of blood cause decreases in πc and increase filtration.***

**πi**, **interstitial oncotic pressure,** is a force favoring filtration. πi is determined by the interstitial fluid protein concentration.
**Normally, because there is little loss of protein from capillaries, there is little protein in interstitial fluid, making πi quite low.**

**Task 1.19.** Explain changes of water balance in case of:

1) *oncotic pressure rises* _____
_____
_____

2) *oncotic pressure drops* _____
_____
_____

**Task 1.20. Give definition of hypoproteinemia and hyperproteinemia. Define the causes of both conditions.**

**Hypoproteinemia**_____
_____

| Relative hypoproteinemia | Absolute hypoproteinemia |
|---|---|
| | |

**Hyperproteinemia**_____
_____

| Absolute hyperproteinemia | Relative hyperproteinemia |
|---|---|
| | |

## ACID-BASIC BALANCE AND BLOOD pH

**Task 1.21. Fill in the facts about acid-base balance**

- Normally, systemic acid-base balance is well regulated with arterial pH between _____ and _____;
- intracellular pH is usually approximately _____.
- **pH value of arterial blood is _____,**
- **of venous blood – _____**
- A difference is explained by _____
- Intracellular and extracellular buffers are the most immediate mechanism of defense against changes in systemic pH.
- A buffer is

_____

_____

_____

**acidosis is** _____

**alkalosis is**_____

**Task 1.22. Systems regulating acid-base balance**

There are 3 primary systems that regulate the $H^+$ concentration in the body fluids to prevent acidosis or alkalosis:

| № | | Function |
|---|---|---|
| 1 | **chemical acid-base buffer systems** | |
| 2 | **respiratory center** | |
| 3 | **kidneys** | |

**Task 1.23.** *pH limits compatible with life are: from _____ to _____*

**Task 1.24.** Complete the table to characterize buffer systems of an organism:

| Name of buffer system | Its components | Properties |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

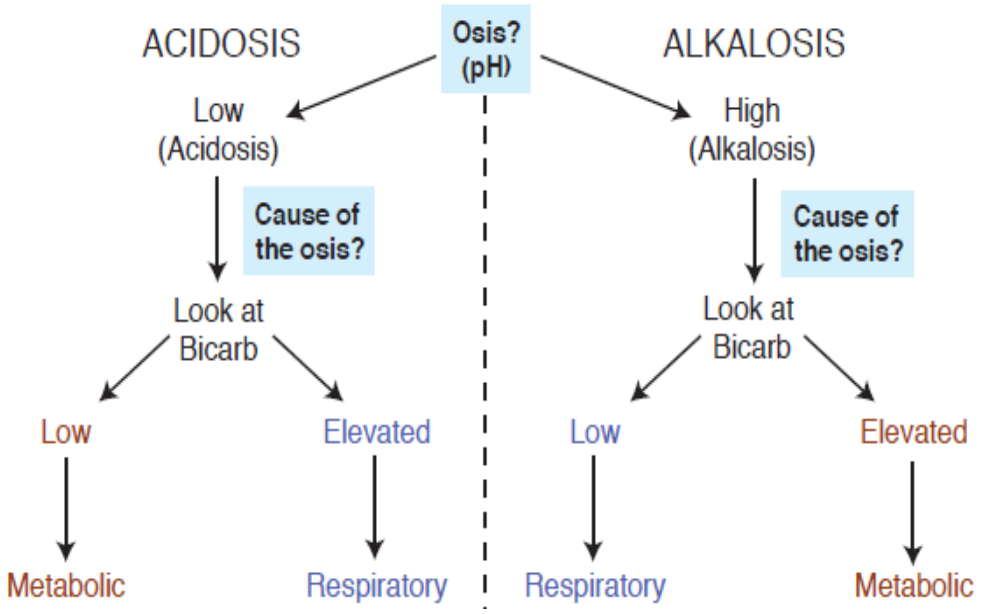
**Task 1.25. Calculate pH of blood using Henderson-Hasselbalch equation.**

**3 measurements to determine the pH:**

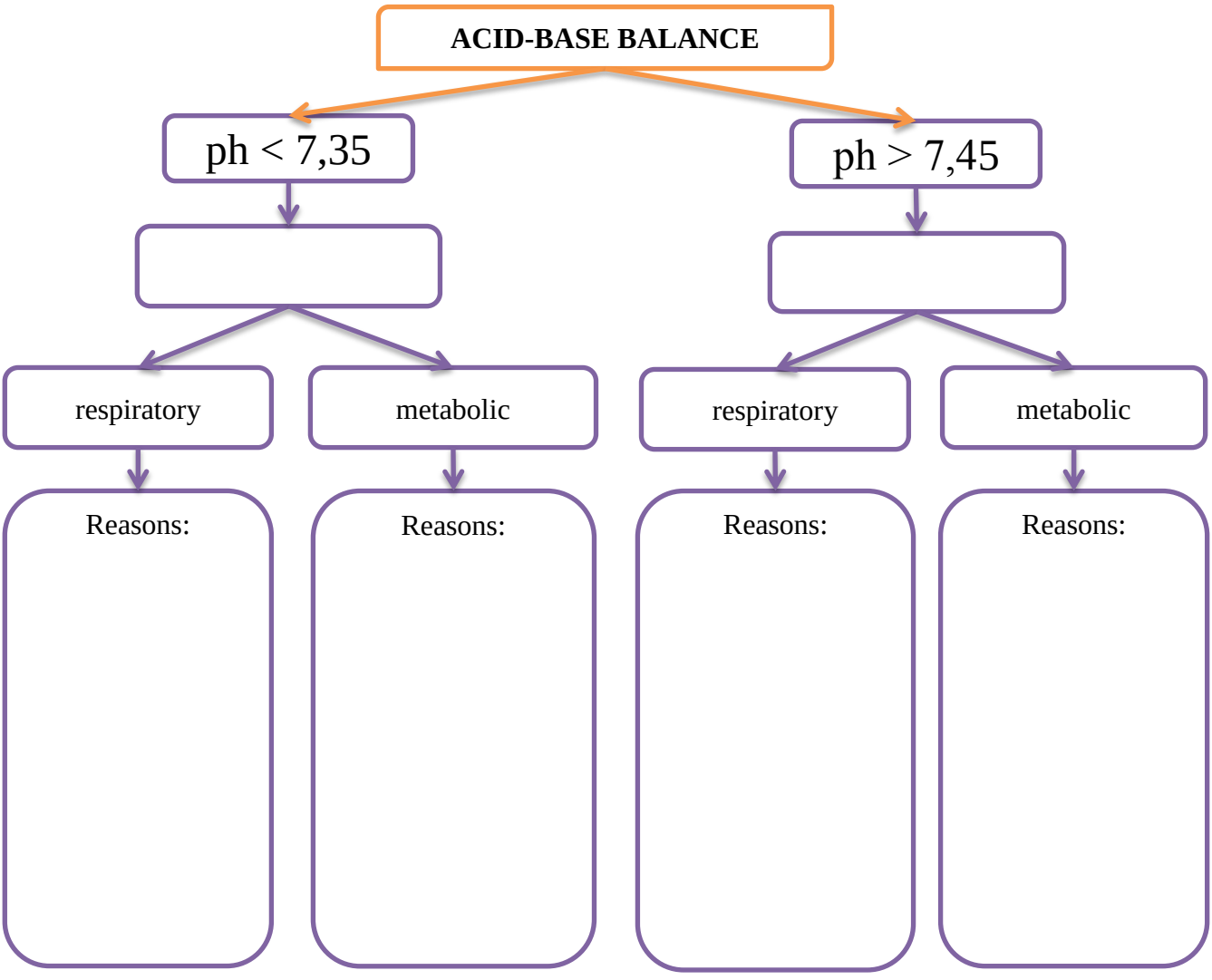
1. **Normal $HCO_3^-$ is 22–28 mEq/l**
2. **Normal $PCO_2$ – 35–45 (40) mm Hg**
3. **Normal pH 7,4 (7,35 – 7,45)**
4. **Constant of $H_2CO_3$ dissociation – 6.1**
5. **Solubility of $CO_2$ in blood – 0.03**

- pH = 6,1 + log $\frac{[HCO3-]}{0{,}03 \times PCO_2}$
- pH =
- pH =
- pH =
- pH =
- **$HCO_3$ – is higher, pH is higher; $HCO_3$ – is lower pH is lower;**
- **$PCO_2$ is high – low pH; $PCO_2$ is low – high pH**

**Algorithm of AB state analysis**




**Task 1.26.** *Complete the table. Maintainance the acid-base balance of organism.*



## 2. Physiology of erythrocytes and hemoglobin

**Task 2.1.** *Complete the table to define erythron*

ERYTHRON is _____

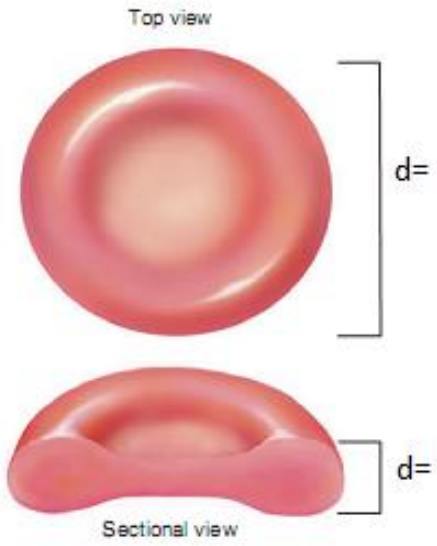
_____

_____

It includes:

Final adaptive result: _____

_____




**Task 2.2.** *Give structural and functional characteristics of RBC.*

*Morphology:* _____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

*Functions:*

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

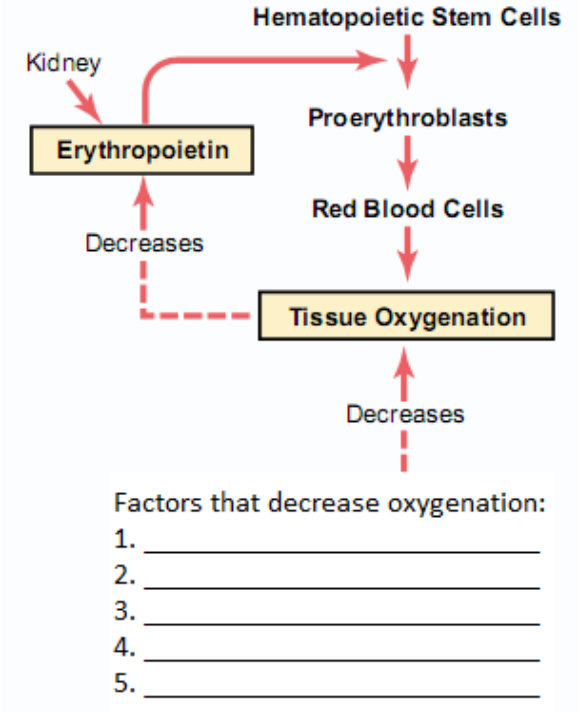
**Task 2.3.** *Name the physiological properties of RBC:*

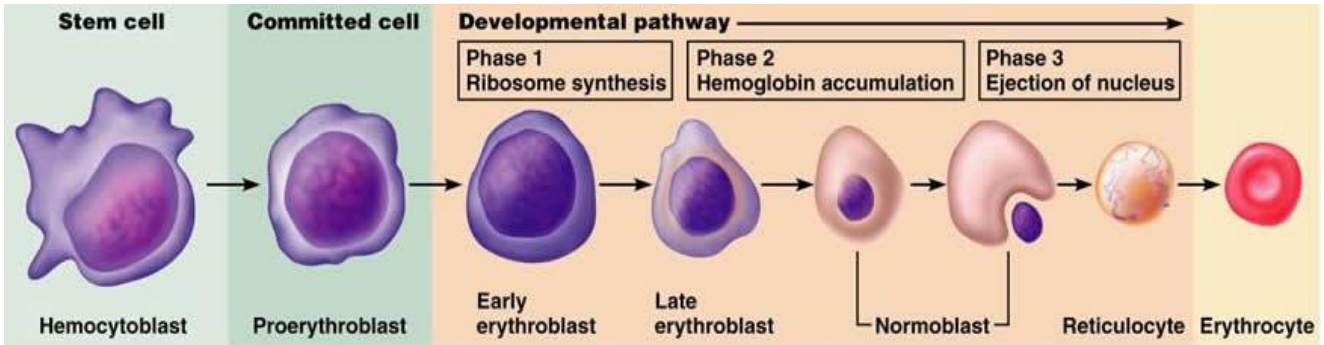
- _____
- _____
- _____
- _____

**Task 2.4.** *Define the factors influencing to erythropoesis.*

- _____
- _____
- _____
- _____
- _____
- _____
- _____
- _____

**Task 2.5.** *Study the scheme «**Functions of erythropoietin mechanism to increase production of RBC when tissue oxygenation decreases**» and complete it:*



**Task 2.6. Regulation of Erythropoiesis**

_____ is main regulator of RBC production.

The following can reduce tissue oxygenation:

1. _____
2. _____
3. _____
4. _____

**Leading to**

- ✓ **Secretion of erythropoietin by endothelial cells in renal cortical peritubular capillaries**
- ✓ **It stimulates production of proerythroblast**
- ✓ **Increasing RBC production**

**Task 2.7. Fill in the table.**

| № | Parameter | Males values | Females values |
|---|---|---|---|
| 1 | Erythrocyte count | | |
| 2 | ESR | | |
| 3 | Hematocrit | | |
| 4 | Hemoglobin | | |
| 5 | Reticulocyte count | | |

**Task 2.8.** *Complete the table to define clinical significance of RBC content changes*

| **Erythrocytosis is** _____ _____ | | **Erythropenia is** _____ _____ | |
|---|---|---|---|
| **relative** | **absolute** | **relative** | **absolute** |
| | | | |

## Physiological properties of RBC

**Task 2.9. Give physiological explanation of Erythrocyte Sedimentation Rate (ESR)**

In presence of an anticoagulant, rate of settling-down of RBCs in specimen of blood which is allowed to stand in a glass tube of uniform bore, is called ESR

Male ESR: _____;

Female ESR: _____

The RBCs sediment because their density is _____ (RBC – _____ $kg/m^3$) than that of plasma (_____ $kg/m^3$); this is particularly so, when there is an alteration in the distribution of charges on the surface of the RBC (which normally keeps them separate form each other) resulting in their coming together to form large aggregates known as rouleaux.

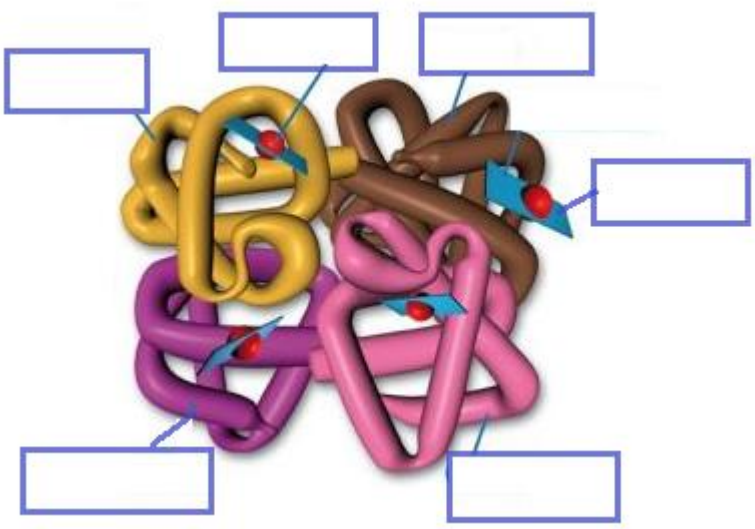
**Task 2.10**. *List factors influencing to the ESR*

| Factors which increase ESR | Factors which decrease ESR |
|---|---|
| | |
| | |
| | |
| | |

**Task 2.11. Red blood cell fragility (Osmotic resistance)**

In a _____ environment (e.g. _____ NaCl or distilled water), an influx of water occurs: the cells swell, the integrity of their membranes is disrupted, allowing the escape of their hemoglobin (**hemolysis**) which dissolves in the external medium.

**Task 2.12.** *Label the main structural components of hemoglobin molecule and describe its chemical structure*



_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

**Task 2.13.** *Determine the types of Hb and complete the table*

| Type | Peculiarities of composition | Period of ontogenesis | Affinity to $O_2$ |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

## From fetal to adult hemoglobin: Alpha Always; Gamma Goes, Becomes Beta

**Task 2.14. Calculate Oxygen content of blood and oxygen delivery to tissues using following formulas.**

- **$O_2$ content = (1.34 × Hb × $Sao_2$) + (0.003 × $Pao_2$) = _____**
- Hb = hemoglobin level (normal Hb amount in male blood is **male: 13.5–17.5 g/dL and** female: 12.0–16.0 g/dL).
- $Sao_2$ = arterial $O_2$ saturation (98 % if $PaO_2$ is 100 mm Hg)
- ***Oxygen saturation*** **is the fraction of [oxygen]-saturated hemoglobin relative to total hemoglobin in the blood.**
- $Pao_2$ = partial pressure of $O_2$ in arterial blood (100 mm Hg)
- Normally 1 g Hb can bind 1.34 mL $O_2$;
- $O_2$ binding capacity ≈ 20.1 mL $O_2$/dL of blood.

$O_2$ delivery to tissues = cardiac output × $O_2$ content of blood = _____

- cardiac output – 4–6 l/min

The normal oxygen transport 640 to 1400 mL/min, or 500 to 600 mL/min/$m^2$.

**Task 2.15.** *Complete the following statements:*
Color index (CI) of erythrocytes is the ratio _____
_____
_____
If the CI is in the range 0.85–1.1, erythrocytes are called _____
If the CI is more than 1.1, erythrocytes are called _____
If the CI is in less than 0.85, erythrocytes are called _____

**Task 2.16.** *Define the hemoglobin compounds:*

**Physiological compounds**

| Name | Formula | Compartment of formation and localization |
|---|---|---|
| 1. | | |
| 2. | | |
| 3. | | |
| 4. | | |

**Pathological compounds**

| Name | Formula | Reasons of their formation |
|---|---|---|
| 1. | | |
| 2. | | |
| 3. | | |

**Task 2.17.**

*Types of hemolysis:*

Hemolysis is _____

_____

1. _____

_____

2. _____

_____

3. _____

_____

4. _____

_____

5. _____

_____

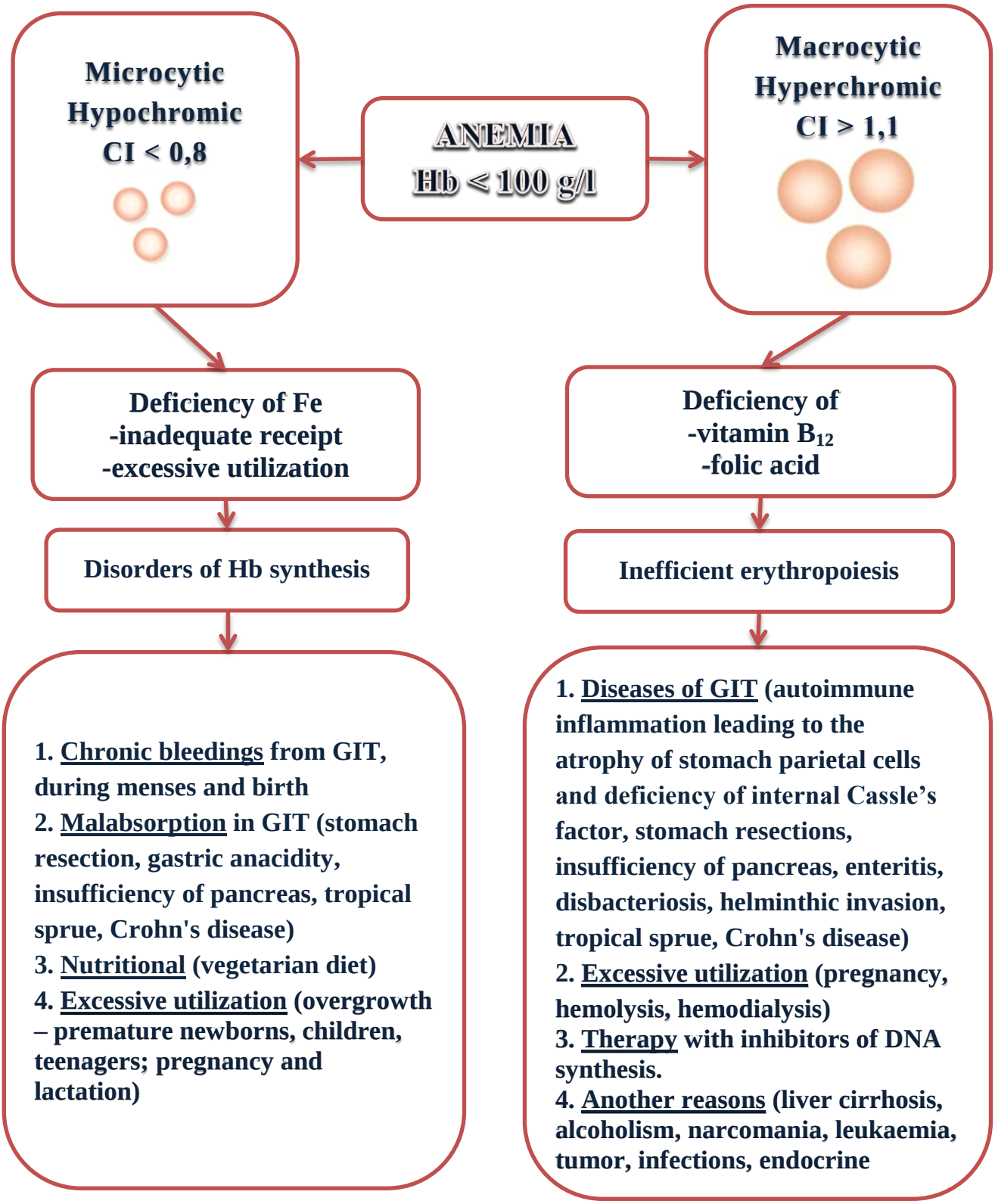



***Figure 1.*** **Morphological classification of anemia, their etiology and genesis**

## 3. Blood protective functions: physiology of leukocytes.

**Task 3.1.** *Determine the normal content of leukocytes in blood*

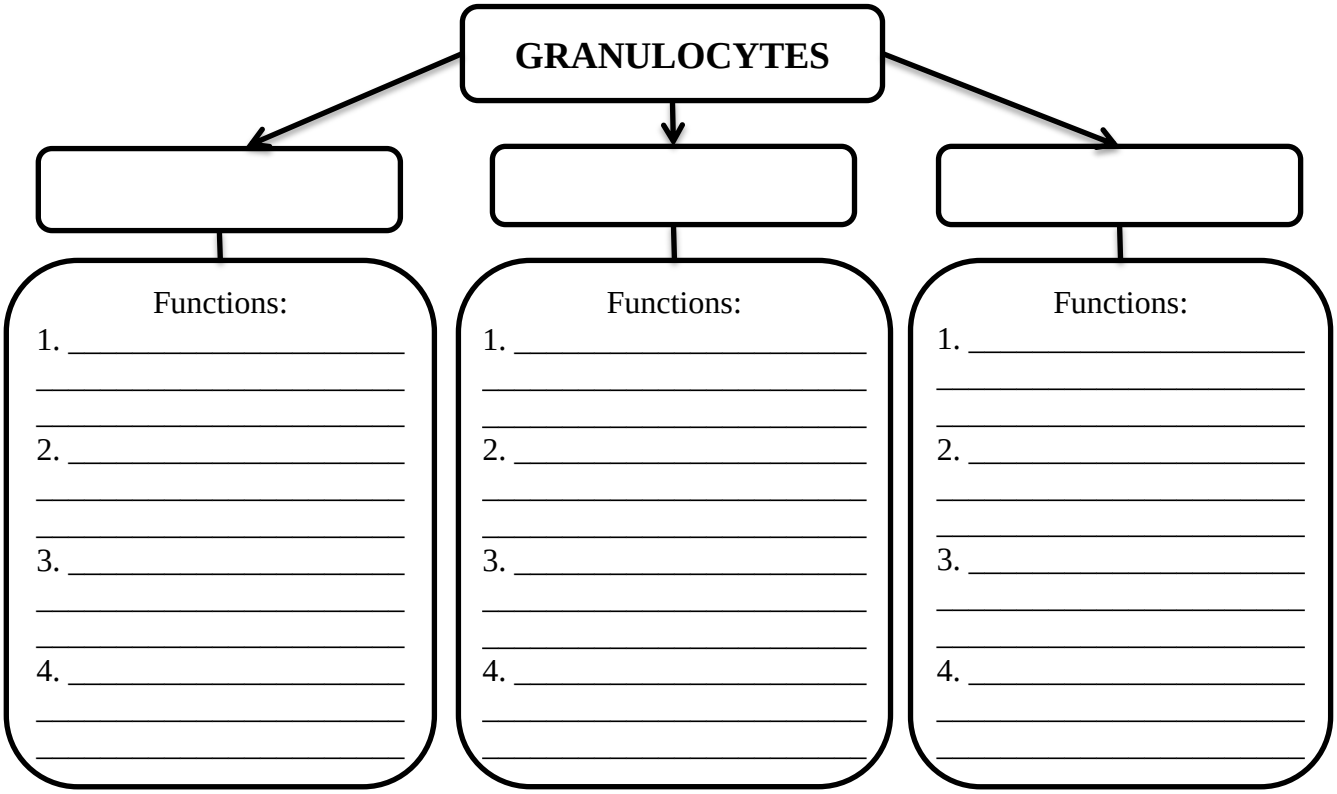
_____

_____

**Task 3.2.** *Complete the following table and define the WBC differential*

| granulocytes | | | | | agranulocytes | |
|---|---|---|---|---|---|---|
| neutrophils | | | basophils | eosinophils | monocytes | lymphocytes |
| | | | | | | |
| | | | | | | |

**Task 3.3.** *Complete the following table*

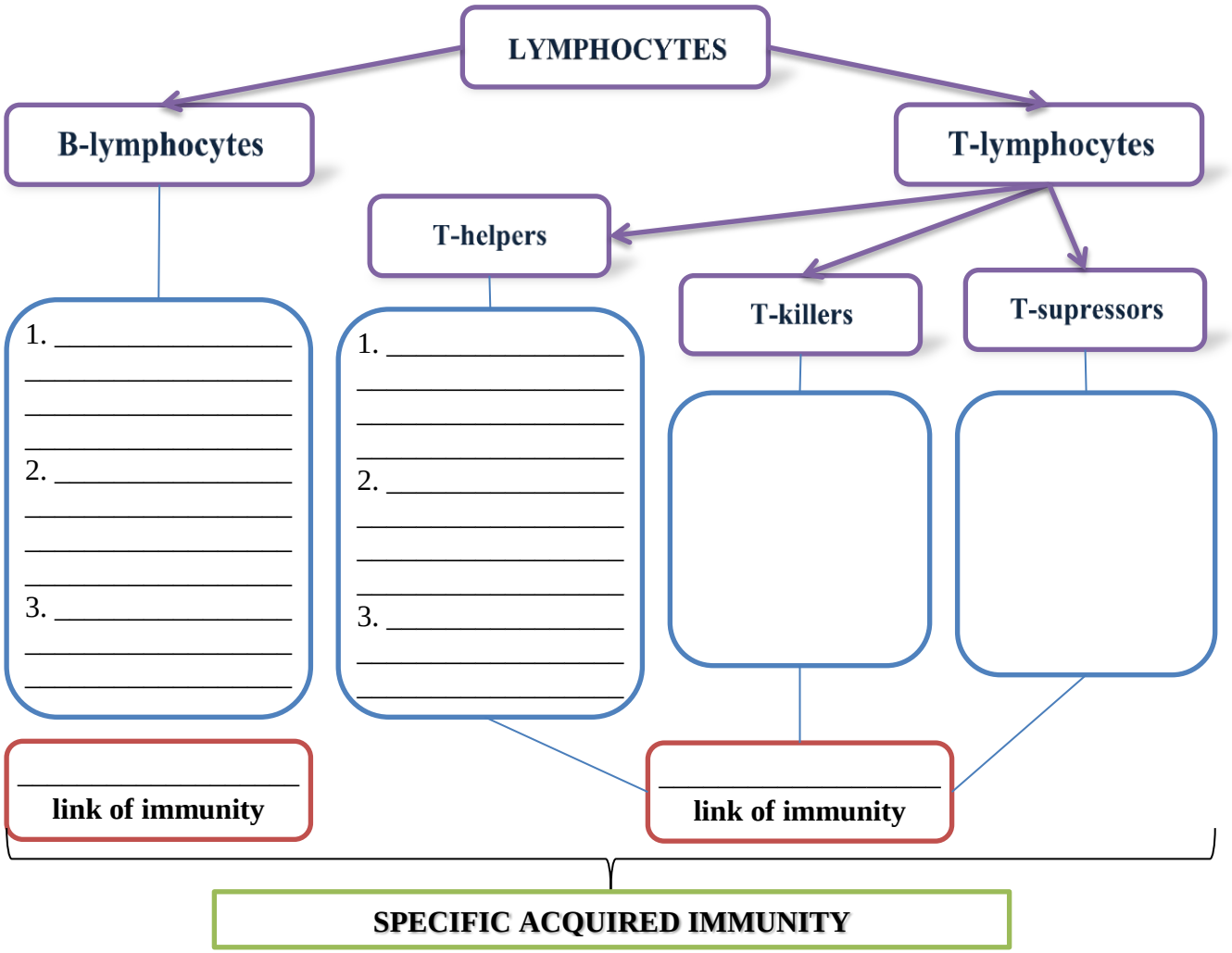



Final adaptive result:

**Task 3.4.** *Complete the following table "Functions of agranulocytes"*

| *Agranulocytes* | Functions |
|---|---|
| monocytes | |
| lymphocytes | |

**Task 3.5.** *Complete the following scheme describing functions of lymphocytes:*



**Task 3.6.** *Complete the following table to compare the mechanisms of immunity:*

| ***Humoral immunity*** | ***Cellular immunity*** |
|---|---|
| | |

**Task 3.7.** *Explain the mechanism of antibodies production:*

_____
_____
_____
_____
_____
_____
_____
_____

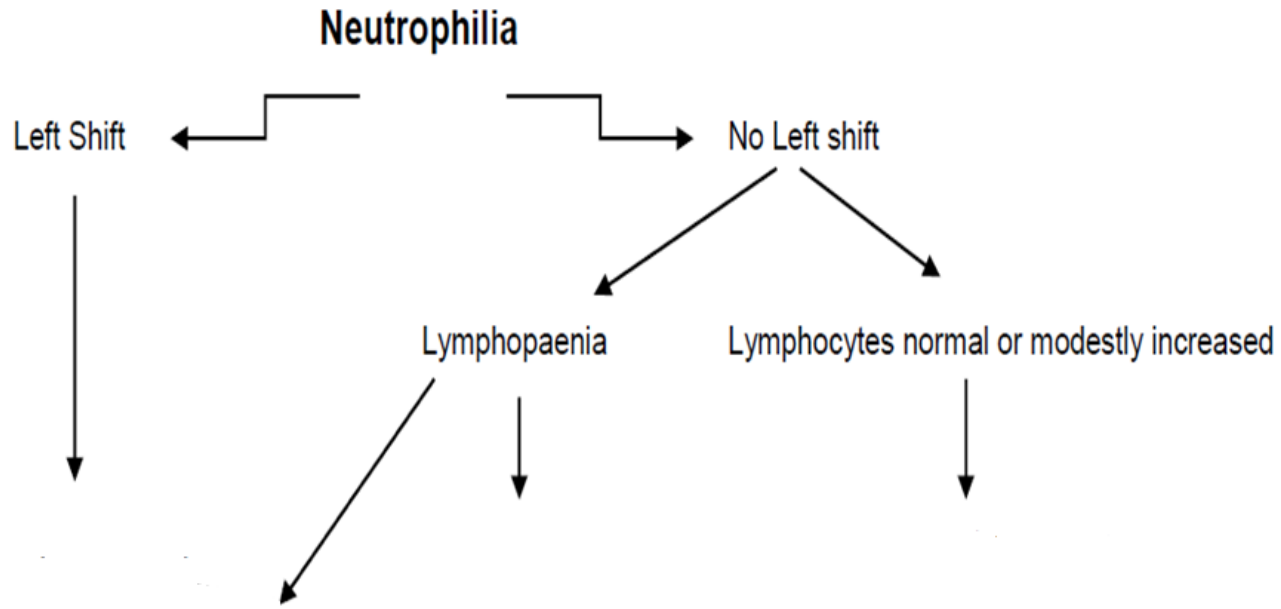
**Task 3.8.** *Complete the following table to define the types of leukocytes content changes:*

| **Leukocytosis is _____** _____ | | **Leukopenia is _____** _____ | |
|---|---|---|---|
| **physiological** | **reactive** | **physiological** | **pathological** |
| | | | |

**Task 3.9.** *Define possible peculiarities of inflammatory, stress and excitement leukogram. Fill in the table.*

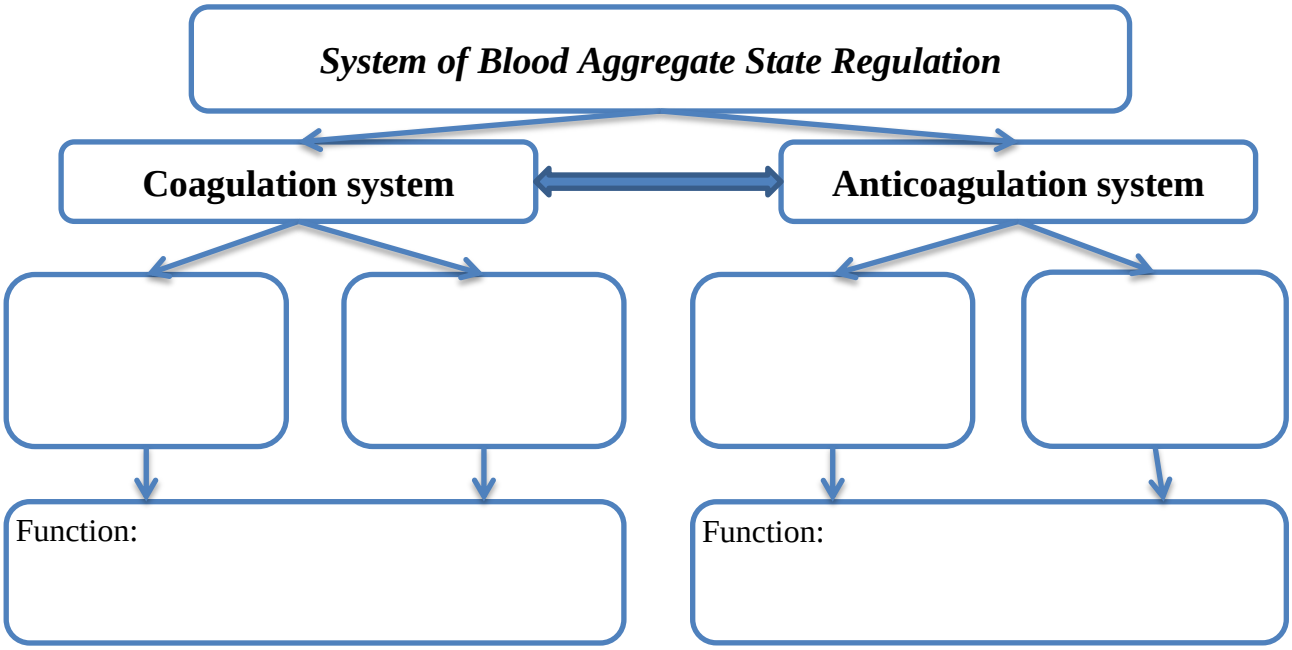
| Condition | Peculiarities |
|---|---|
| **inflammatory** | |
| **stress** | |
| **excitement** | |

**Task 3.10. Complete the scheme.**



## 4. Types and physiological mechanisms of the blood coagulation. Physiology of platelets

**Task 4.1.** *Complete the scheme «The System of Blood Aggregate State Regulation» and define the functions of its components*




**Task 4.2.** Define the main components of coagulation process

| Main components of coagulation process | | |
|---|---|---|
| | | |

**Task 4.3.** *Complete the following table "Factors of blood coagulation"*

**Cellular factors are synthesized by blood formed elements**

| Nomenclature | Name | Functions |
|---|---|---|
| **$P_1$** | | |
| **$P_2$** | | |
| **$P_3$** | | |
| **$P_4$** | | |
| **$P_5$** | | |

| Nomenclature | Name | Functions |
|---|---|---|
| $P_6$ | | |
| $P_7$ | | |
| $P_8$ | | |
| $P_9$ | | |
| $P_{10}$ | | |
| $P_{11}$ | | |
| Factor of Willebrandt | | |
| Thromboxane $A_2$ | | |
| Fibronectin | | |

**Plasma coagulation factors**

| Nomen-clature | Name | Organ producing | Functions |
|---|---|---|---|
| I | | | |
| II | | | |
| III | | | |
| IV | | | |
| V | | | |
| VI | | | |
| VII | | | |

| Nomen-clature | Name | Organ producing | Functions |
|---|---|---|---|
| **VIII** | | | |
| **IX** | | | |
| **X** | | | |
| **XI** | | | |
| **XII** | | | |
| **XIII** | | | |
| **XIV** | | | |
| **XV** | | | |

**Task 4.4. Fill in the table** «Morphology, life span, normal value and function of platelets»

| Morphology, life span and normal value | Functions |
|---|---|
| | |

**Task 4.5. Fill in the table «**Factors affecting Blood Platelet Count»

| Increasing factors | Decreasing factors |
|---|---|
| | |
| | |
| | |
| | |

**Task 4.6.** *Complete the table «Vascular-platelet hemostasis» and describe its stages*

| | Name of stage | Description of processes |
|---|---|---|
| **1** | | |
| **2** | | |
| **3** | | |
| **4** | | |
| **5** | | |
| *Final adaptive result is* _____ _____ | | |

**Task 4.7.** Define the receptors of platelets and their function.

| № | Type of receptor | Function |
|---|---|---|
| **1** | **GP Ia** | |
| **2** | **GP Ib** | |
| **3** | **P2Y12** | |
| **4** | **GP IIb-IIIa** | |
| **5** | **TXA2** | |

**Task 4.8.** *Complete the table «Coagulation hemostasis» and describe its stages*

| Name of stage | Duration | Description of processes |
|---|---|---|
| **I. _____ _____** | | |
| **Extrinsic (tissue) mechanism** | | |
| **Intrinsic (blood) mechanism** | | |
| **II. _____ _____** | | |
| **III. _____ _____** | | |

*Final adaptive result is* _____
_____
_____
_____
_____
_____
_____
_____
_____

**Task 4.9.** *Draw the scheme «Coagulation Hemostasis»*

**Task 4.10.** *Complete the scheme «After-phase of blood clotting»*

| ***Retraction*** | ***Fibrinolysis*** |
|---|---|
| | *I.* |
| | *II.* |
| | *III.* |

**Task 4.11.** *Explain the significance of anticoagulation system*

_____

_____

**Task 4.12.** *Define the factors of blood fluidity maintaining*

1. _____

_____

2. _____

_____

3. _____

_____

4. _____

_____

_____

**Task 4.13.** *Complete the scheme "Blood Anticoagulants"*

| **№** | **Substance** | **Effect** |
|---|---|---|
| 1 | Tissue factor pathway inhibitor (TFPI) | |
| 2 | Protein C | |
| 3 | Antithrombin III | |

**Task 4.14. Define the effects of following anticoagulants. Fill in the table.**

| Substance | EFFECT |
|---|---|
| *Vitamin K deficiency* | |
| *Heparin* | |
| *Warfarin* | |
| *Aspirin* | |
| *Sodium Citrate* | |

**Task 4.15.** *Define the normal values of coagulogram.*

| Index | Value and clinical significance |
|---|---|
| **Bleeding time** | |
| **Partial thromboplastin time (activated)** | |
| **Platelet count** | |
| **Prothrombin time** | |
| **Thrombin time** | |
| **international normalized ratio(INR)** | |

## 5. Blood protective functions. Blood types.

**Task 5.1.** *Complete the following statements:*
Different blood types are determined by the hereditary presence or absence of antigens on the surface of erythrocytes. They are called _____ and they are of 2 types: _____ and _____.
In the blood serum the antibodies against these antigens are present. They are called _____ and they are also of 2 types: _____ and _____.

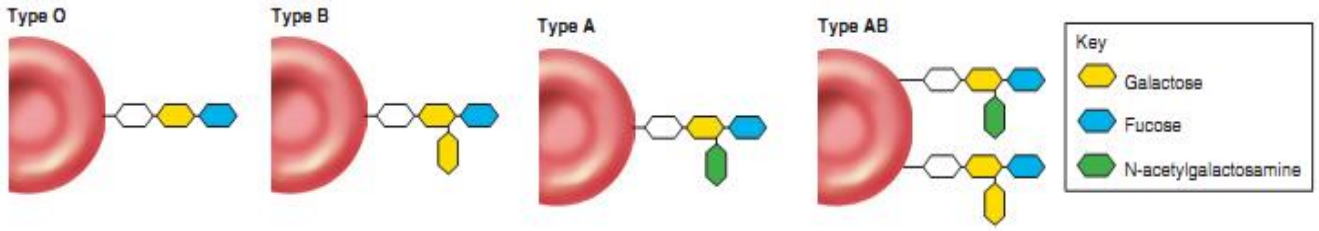
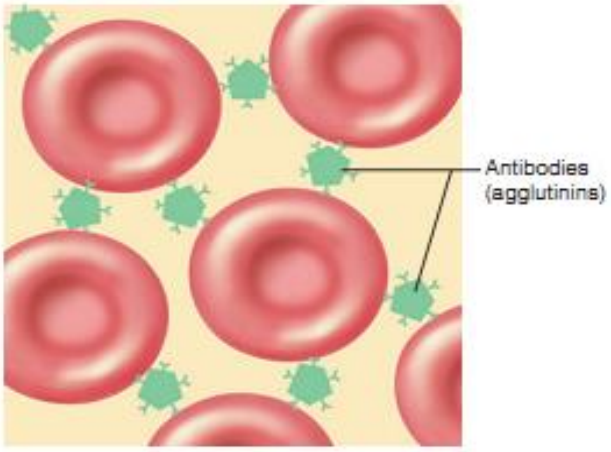



***Figure 1.*** **Chemical Basis of the ABO Blood Types.** *The terminal carbohydrates of the antigenic glycolipids are shown. All of them end with galactose and fucose (not to be confused with fructose). In type A, the galactose also has an N-acetylgalactosamine added to it; in type B, it has another galactose; and in type AB, both of these chain types are present.*




When the same _____ and _____ are present the phenomenon of _____ is observed which is the clumping of RBCs bond together by antibodies.

***Figure 2.*** **Agglutination of RBCs by Antibodies.** *Anti-A and anti-B have 10 binding sites, and can therefore bind multiple RBCs to each other.*

**Task 5.2.** *Complete the following table to classify blood groups according to ABO-system:*

| ***Blood group*** | ***RBCs agglutinogens*** | ***Serum agglutinins*** | ***SI*** |
|---|---|---|---|
| **I** | | | |
| **II** | | | |
| **III** | | | |
| **IV** | | | |

**Task 5.3.** *Study the illustration of the ABO blood typing and explanation for it.*

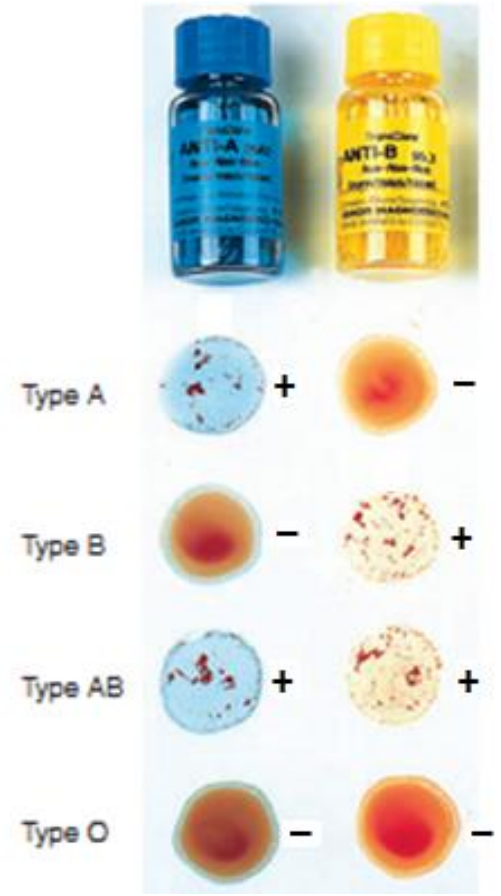



***Figure 3.*** **ABO Blood typing with monoclonal antibodies.**

Each row shows the appearance of a drop of blood mixed with anti-A and anti-B monoclonal antibodies. Pay attention that anti-A reagent is actually the solution of α agglutinins, correspondently Anti-B is the solution of β ones. Blood cells become clumped if they possess the antigens for the antibodies (top row left, second row right, third row both) but otherwise remain uniformly mixed. Thus type A agglutinates only in anti-A; type B agglutinates only in anti-B; type AB agglutinates in both; and type O agglutinates in neither of them.

When standard sera are used for blood typing you have to represent exactly that serum of II group contents β agglutinins and reacts with RBCs of groups possessing B agglutinogens (III and IV). A serum of III group has α agglutinins and reacts with erythrocytes of groups which content A agglutinogens (II and IV). RBCs of I group possess no agglutinogens and never can agglutinate with any sera. In contrast erythrocytes of IV group with sera of all groups I, II and III.

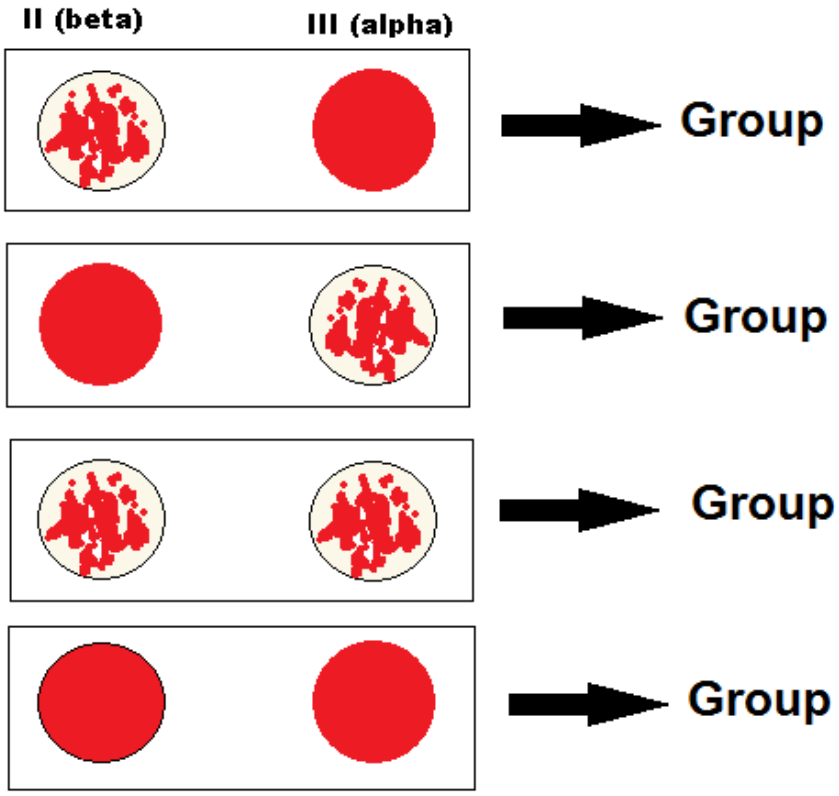
*Use this information to complete the table «Blood typing showing agglutination of different blood types RBCs». Label with «+» agglutination and «−»if it's absent.*

| **Serum Group** | **Erythrocytes group** | | | |
|---|---|---|---|---|
| | **I (O)** | **II (A)** | **III (B)** | **IV (AB)** |
| **I (α and β)** | | | | |
| **II (β)** | | | | |
| **III (α)** | | | | |
| **IV (0)** | | | | |

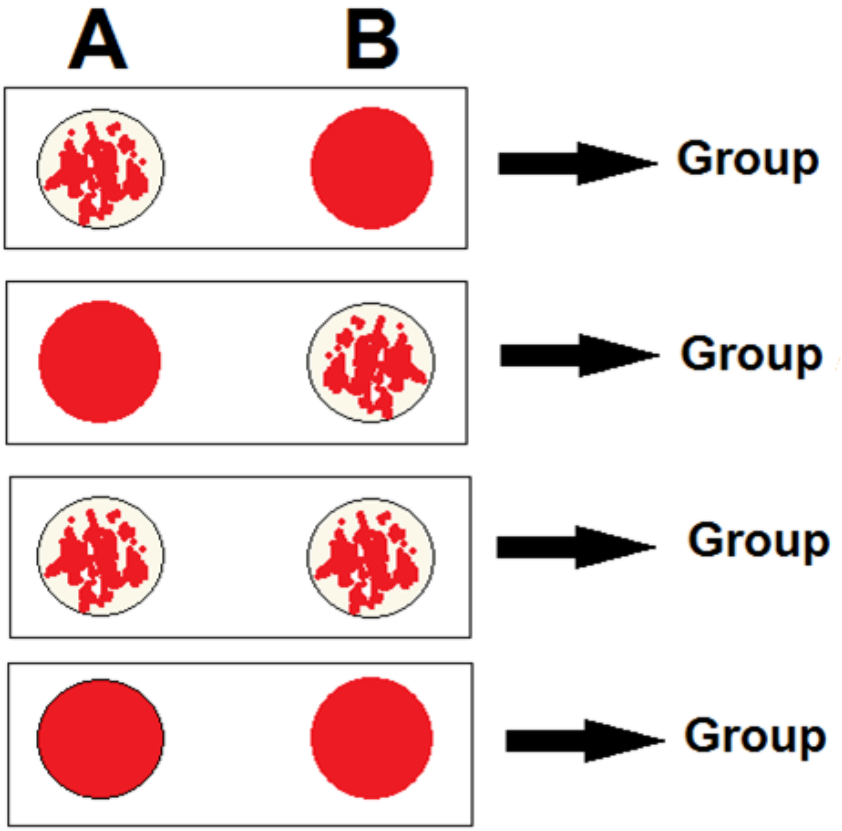
**Task 5.4. Give definition and cause of agglutination.**

_____
_____
_____
_____
_____
_____
_____
_____

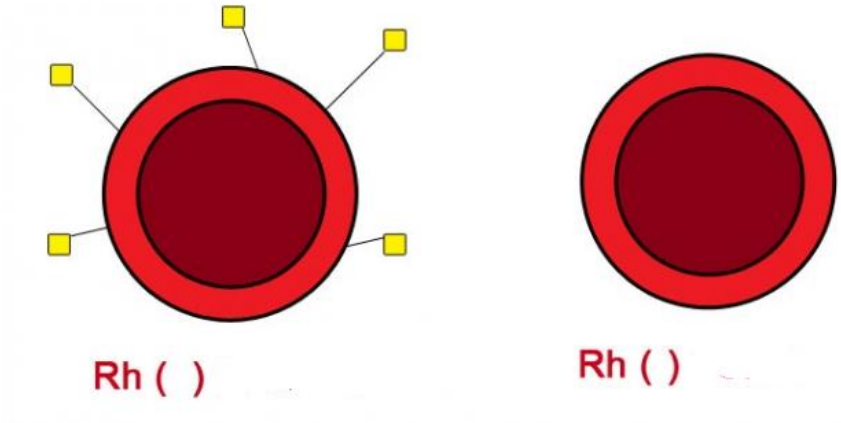
**Task 5.5.** *Explain the blood typing with help of standard sera*




**Task 5.6.** *Explain the blood typing with help of anti-A and anti-B reagents*



**Task 5.7.** *Define the blood types according to the Rh-factor (pay attention that there are no natural antibodies to the Rhesus-agglutinogens)*




**Task 5.8.** *Study the illustration of the Rhesus conflict between mother and fetus*

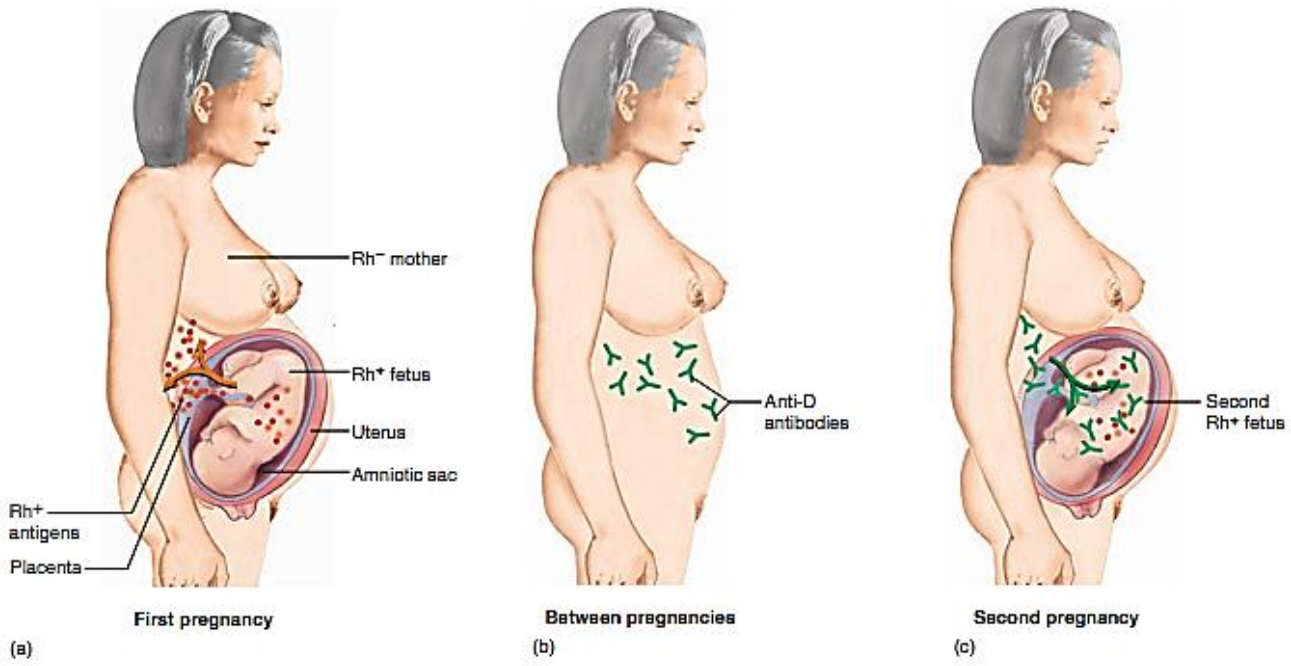



***Figure 4. Hemolytic Disease of the Newborn (HDN).***

*Explain the mechanism of rhesus-conflict during pregnancy* _____

_____

_____

_____

_____

_____

*Explain why ABO-system don't cause the immune conflict between mother and fetus*

_____

_____

_____

_____

**Task 5.9.** *List the general rules of hemotransfusion*

1. _____

_____

2. _____

_____

3. _____

_____

**Task 5.10.** *List the obligatory tests before the blood transfusion*

1. _____

_____

2. _____

_____

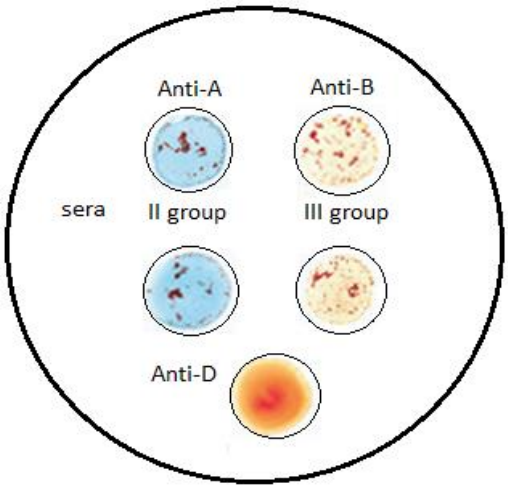
3. _____

_____

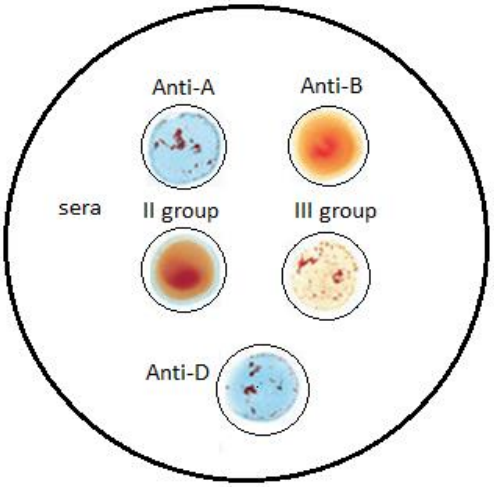
4. _____

_____

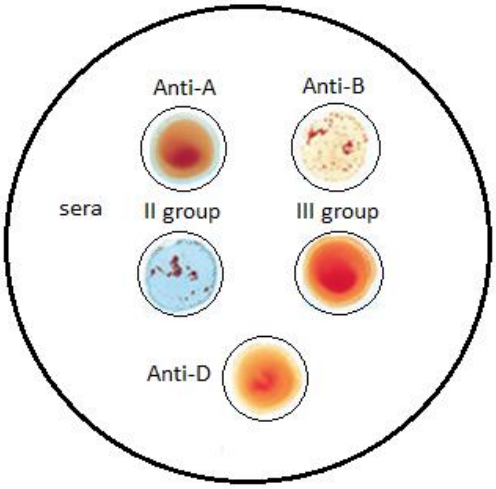
**Task 5.11.** *Determine the blood group and Rh-factor on the pictures*



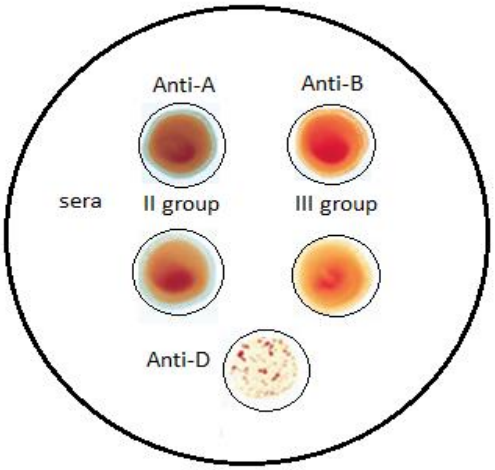

Blood type _____




Blood type _____




Blood type _____

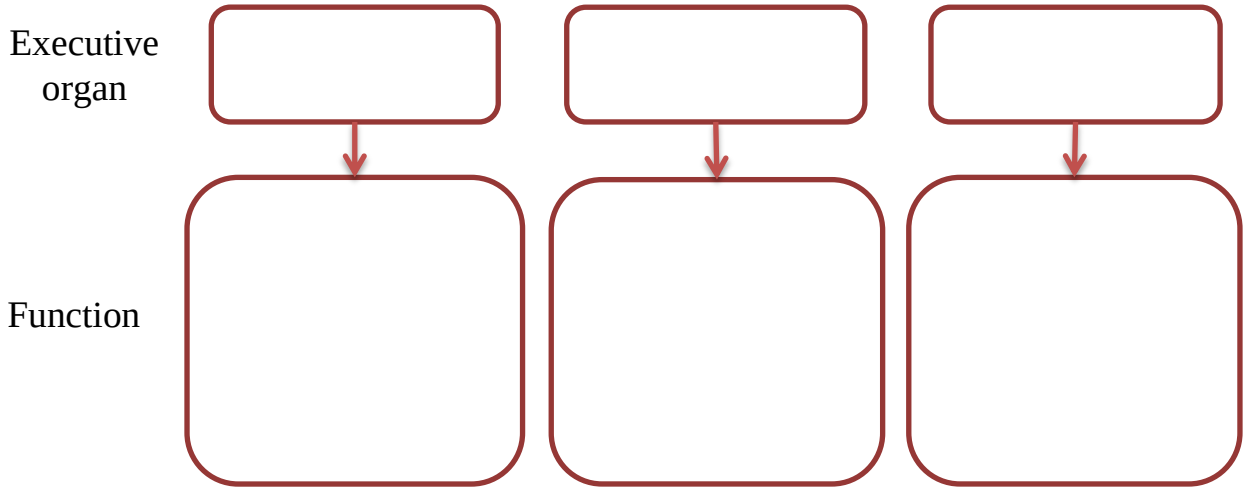



Blood type _____

## PHYSIOLOGY OF HEART

### 6. General characteristic of blood circulation system. Physiological properties of yocardium. Physiological basis of ECG

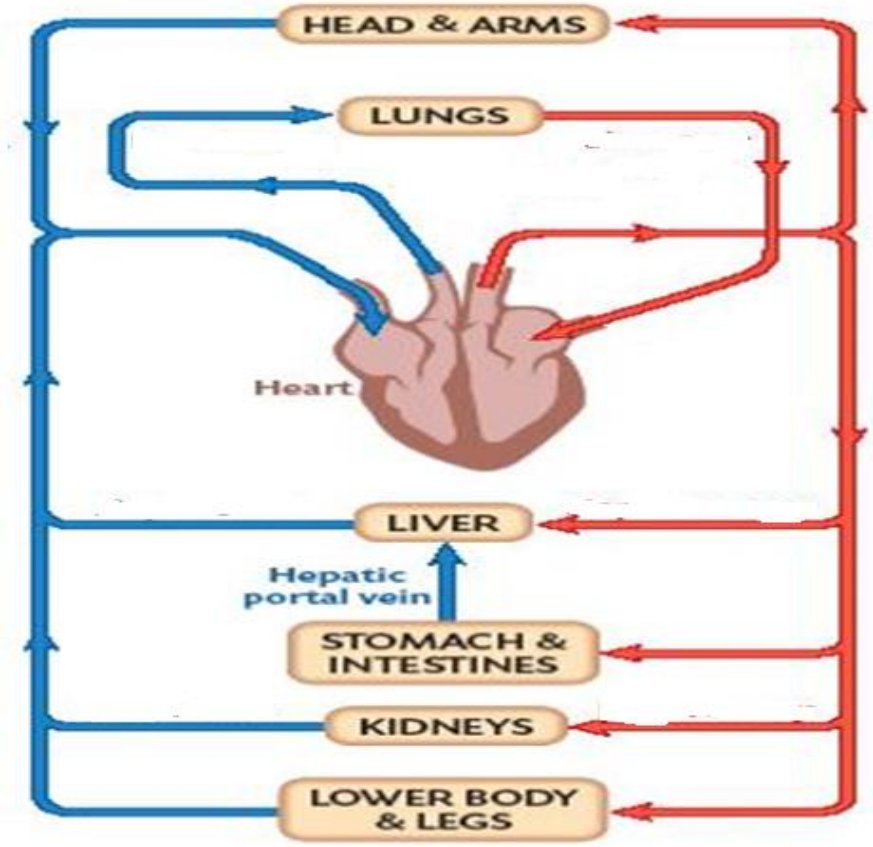
**Task 6.1.** *Draw the scheme of* ***functional system of circulation***



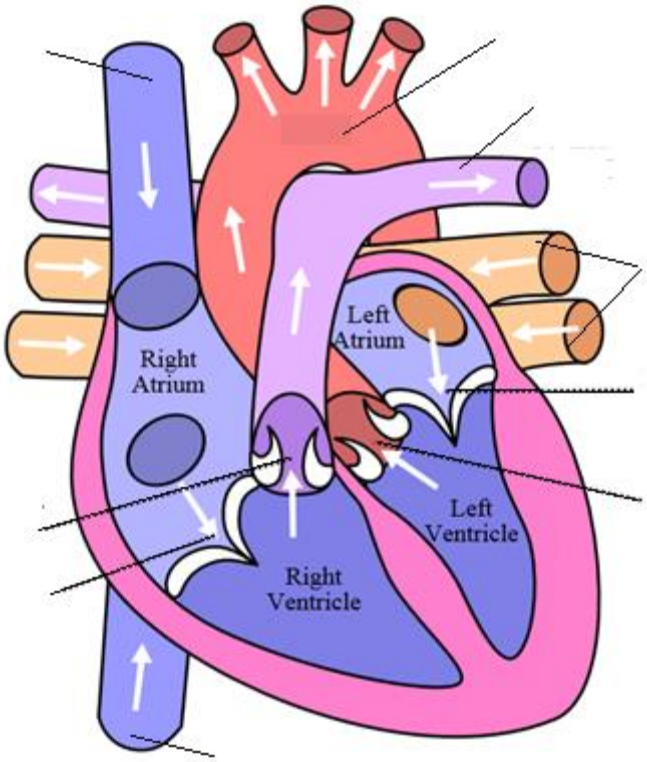

Final adaptive result: _____

_____

**Task 6.2.**Describe pulmonary and systemic circulation step by step labeling with numbers and starting from aorta. Name shown vessels and heart chambers.



**Task 6.3.** *Describe anatomy of heart.*




**Task 6.4.** *Functions of cardiovascular system.*

| Function | Description |
|---|---|
| Heart as a pump | |
| To deliver blood | |
| The vessels from the heart to the tissues | |
| The vessels from the tissues to the heart | |
| Thin-walled blood vessels | |
| Homeostatic functions | |

**Task 6.5.** Give definitions of following terminology.

Stroke volume – _____
_____
Cardiac output –_____
_____
Venous return – _____
_____

Define distribution of cardiac output among following organs^

- ____% –to the brain,
- ____% is delivered to the heart,
- ____% is delivered to the kidneys,
- ____% – GIT
- ____%– Skeletal muscles
- ____%– Skin

Complete the following statements using appropriate symbols (= or ≤ or ≥)
In normal physiological state

***Venous return to the right atrium _____ cardiac output from the left ventricle.***

***cardiac output of RV _____cardiac output of LV***

**Task 6.6.** List heart valves and define their role.

| № | Valve | Localization | Function |
|---|---|---|---|
| 1 | | | 1. |
| 2 | | | 2. |
| 3 | | | |
| 4 | | | 3. |

**Task 6.7. Define physiological properties of myocardium as an excitable tissue**

| Physiological properties | | | |
|---|---|---|---|
| | | | |
| **Definitions** | | | |
| | | | |

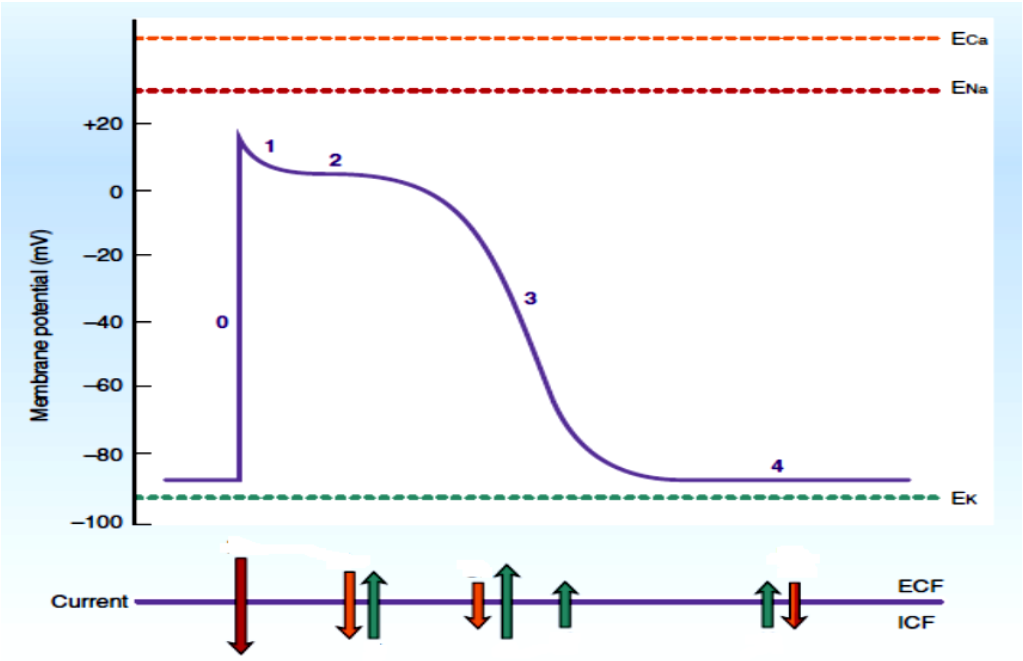
**Task 6.8. Name the stuctures of heart responsible for following properties. Fill in the table.**

| № | properties | Heart structures | Function |
|---|---|---|---|
| 1 | Automaticity | | |
| | | | |
| | | | |
| | | | |
| 2 | Conductivity | | |
| | | | |
| | | | |
| | | | |
| 3 | Contractility | | |
| 4 | Endocrine | | |

**Task 6.9.** ***Complete the table*** **"Conducting system of the heart"**

| *Excitable cells* | *Frequency (ap/min)* | *Description* | *Velocity (m/s)* |
|---|---|---|---|
| **SA-node** | | | |
| **Atrial internodal tracts** | | | |
| **AV-node** | | | |
| **His' bundle** | | | |
| **Purkinje fibers** | | | |
| **Contractile cardiomyocytes** | | | |

**Task 6.10.** Action Potentials of Ventricles, Atria, and the Purkinje System. Define ions influx or efflux in each phase of AP. Name the phases of AP.



**Task 6.11. Fill in the table. Phases of AP.**

| ***Phase*** | ***Membrane conductance*** | ***Type of channels*** | ***Relation to ECG*** |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

*Define the common features of the AP in Ventricles, Atria, and the Purkinje System:*

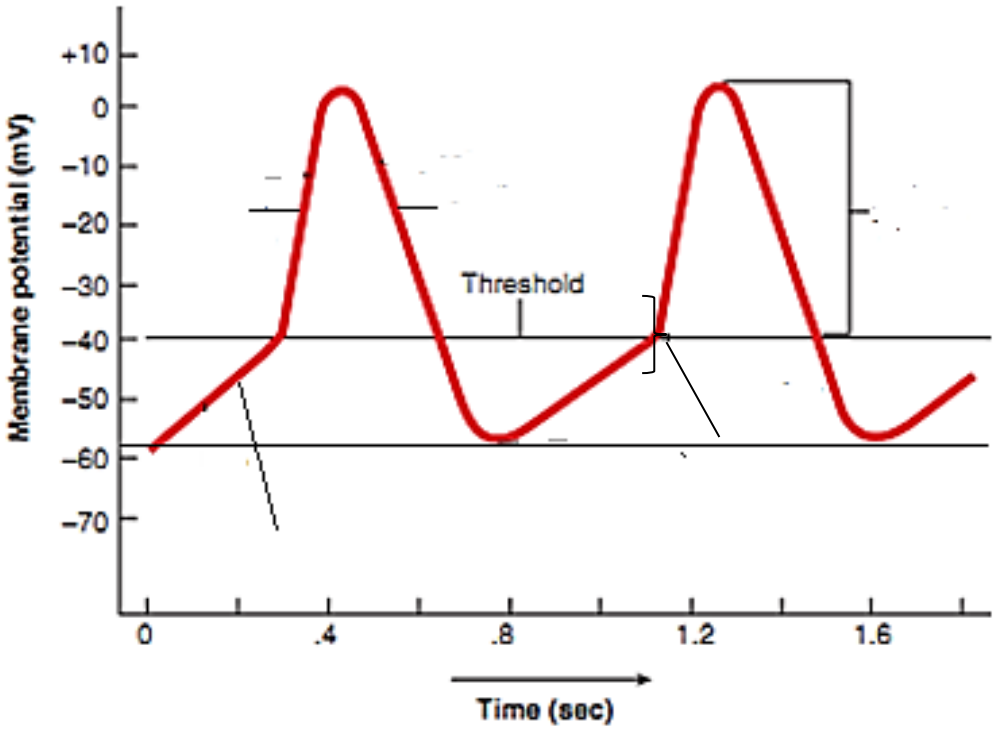
*1.* _____

*2.* _____

*3.* _____

*4.* _____

**Task 6.12.** *Name the phases of action potential of SA node and describe the processes in every phase of AP.*

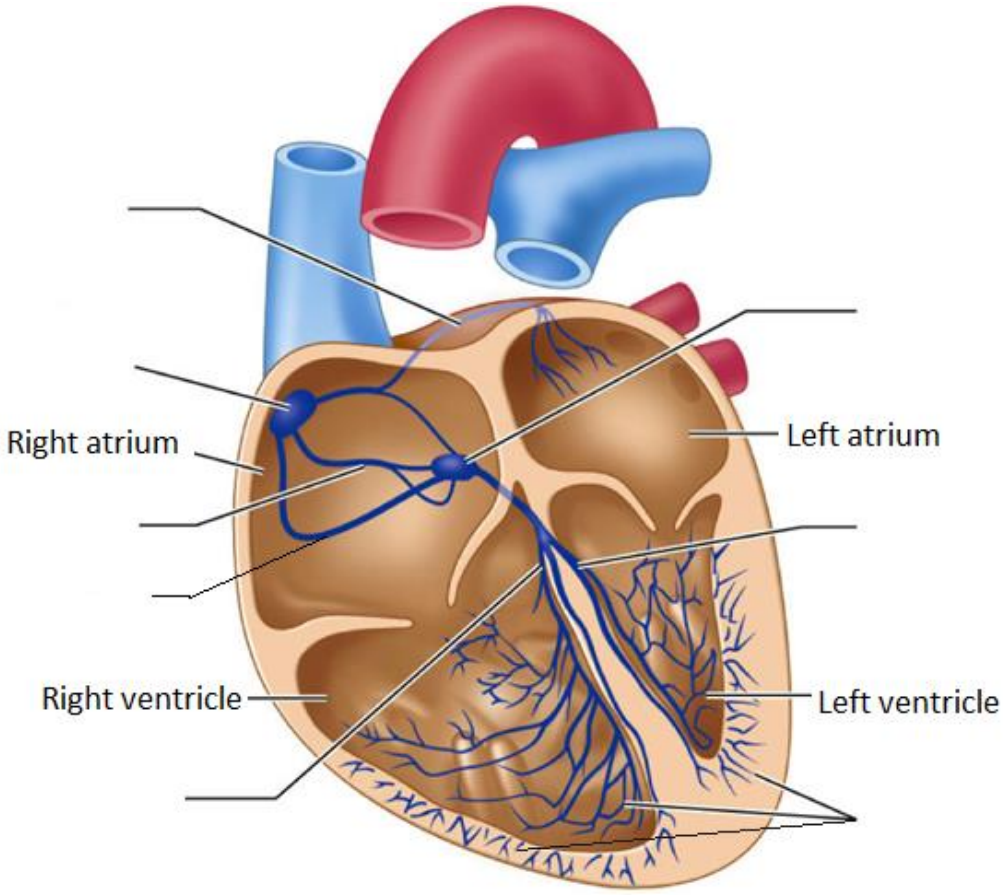



| Phase | Description |
|---|---|
| | |
| | |
| | |

Define the features of the AP of the SA node which are different from those in atria, ventricles, and Purkinje fibers:

1. _____
2. _____
3. _____
4. _____

**Task 6.13.** *Label the structures of heart's conduction system.*




**Task 6.14.** *Define the importance of atrioventricular delay.*

_____

_____

_____

**Task 6.15.** *Describe excitation-contraction coupling by stages.*

1._____

_____

2._____

_____

3._____

_____

4._____

_____

5._____

_____

6._____

_____

7._____
_____
8._____
_____
9._____
_____
10._____
_____

**Task 6.16.** *Give definition of electrocardiography*.

_____
_____
_____
_____

**Task 6.17.** *Give definition of electrocardiogram.*

_____
_____
_____
_____

**Task 6.18.** *Define and describe different leads of ECG. Use illustration to decide this task*

1. **Classical leads (*Einthoven, 1913*)** are _____
_____
_____

**I lead** _____
**II lead**_____
**III lead**_____

2. **Intensified leads *(Goldberger, 1942)*** are _____
_____
_____

**aVR**_____
**aVL**_____
**aVF**_____

3. **Chest leads *(Wilson, 1934)*** are _____
_____
_____

**$V_1$**_____
**$V_2$**_____

$V_3$ _____

$V_4$ _____

$V_5$ _____

$V_6$ _____

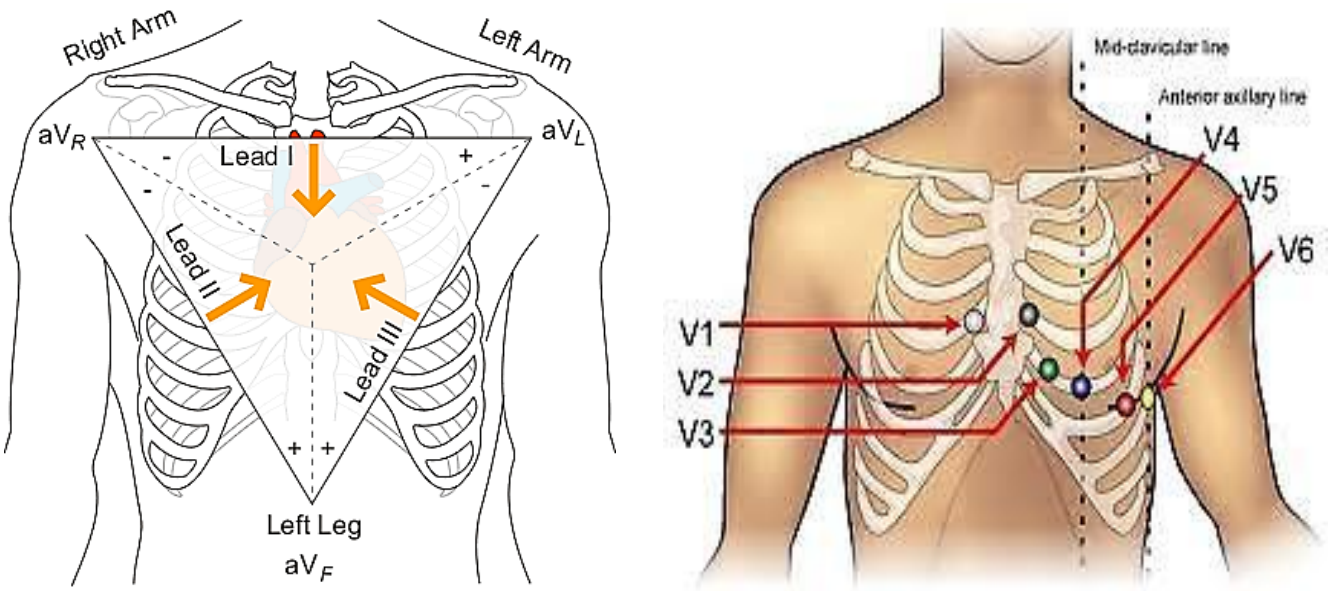
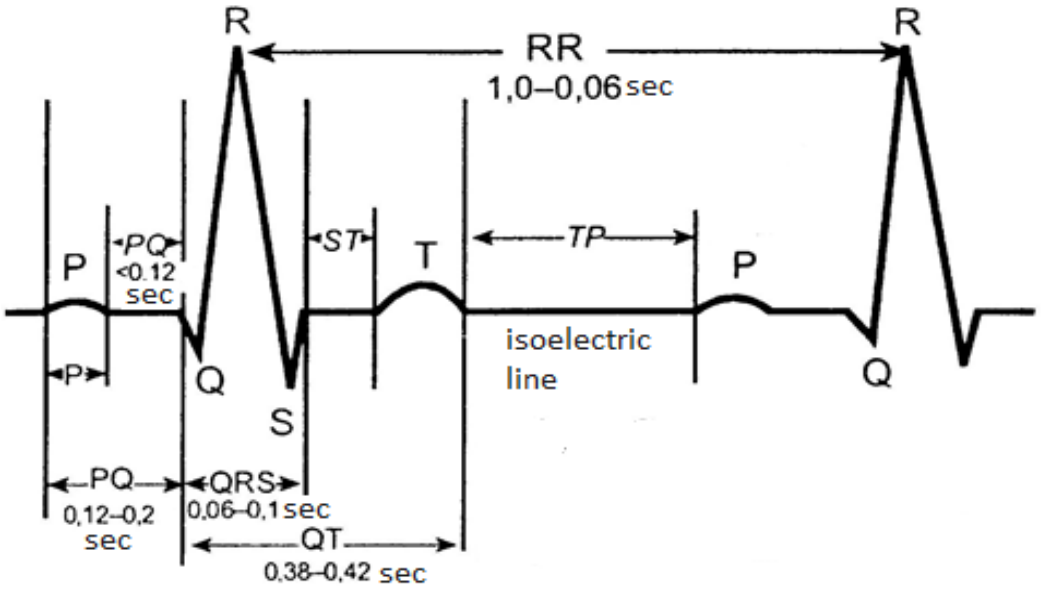



***Figure 1.*** **Different leads used for ECG registration**

**Task 6.19.** *Study the illustration of ECG and complete the following statements*



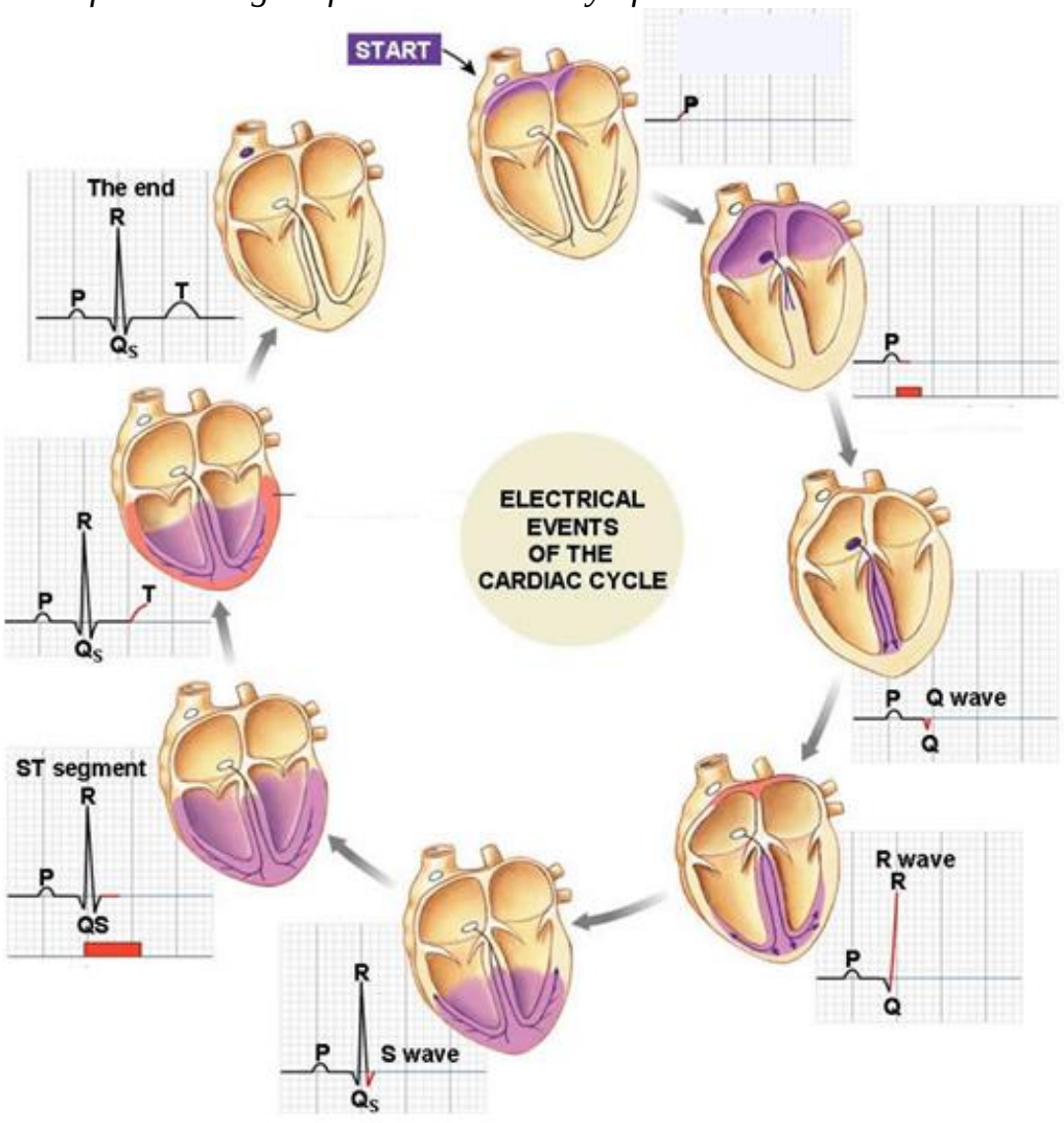

During cardiac cycle these parameters of ECG are recorded:

1) waves. They are _____
2) segments. They are _____
3) intervals. They are _____

**Task 6.20.** *Complete the table for II standard lead using the previous illustration.*

| *Index* | *Electrical activity* | *Duration* | *+ or -* | *Amplitude* |
|---|---|---|---|---|
| **P wave** | | | | |
| **P-Q interval** | | | | |
| **Q wave** | | | | |
| **R wave** | | | | |
| **S wave** | | | | |
| **QRS complex** | | | | |
| **R-R interval** | | | | |
| **S-T segment** | | | | |
| **T wave** | | | | |
| **Q-T interval** | | | | |

**Task 6.21.** *Define the stages of electrical activity of the heart.*



## 7. Heart pumping function

**Task 7.1.** *Give definition of cardiac cycle.*

_____
_____
_____

**VC = VS+VD or AC = AS+AD**

**CC lasts 0.8 sec if HR is 75 bpm**

**CC = 60 sec / 75 bpm = 0,8**

**VC = 0.8 = VS 0.33 + VD 0.47**

**AC = 0.8 = AS 0.1 + AD 0.7**

**Task 7.2.** *Calculate the duration of cardiac cycle if heart rate is*

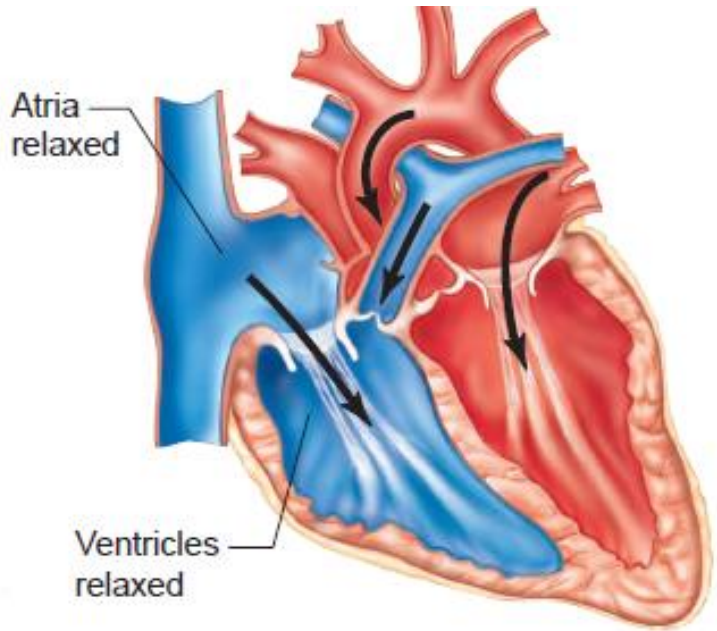
75bpm _____
80bpm_____
60bpm_____

**Task 7.3.** *Describe illustrations representing events happening in heart in each phase of CC.*

*Define the following:*

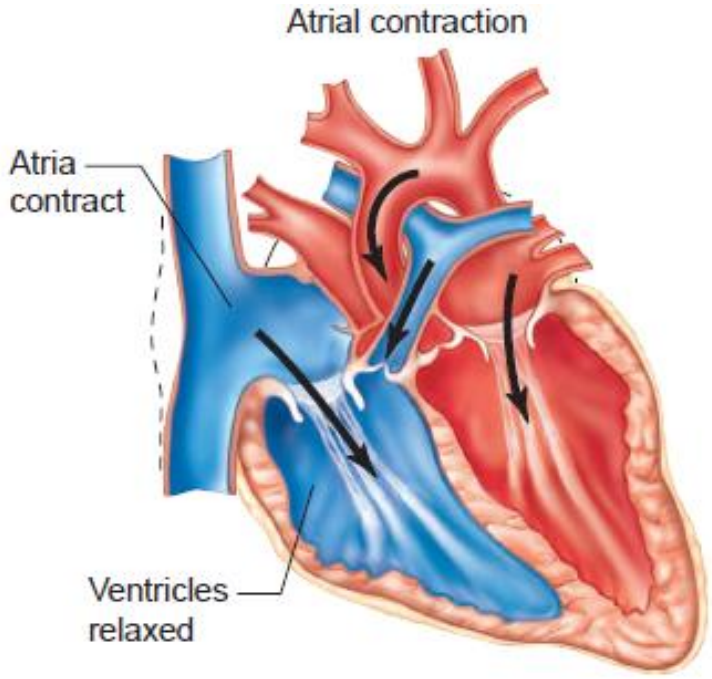
- **Direction of blood flow throughout the heart chambers**
- **2. State of Valves (closed or opened)**
- **3. Value of pressure in each chamber**
- **4. Heart sounds**
- **5. SV, ESV, EDV**

**1. Total pause or total diastole of the heart precedes atrial systole – 0,37 sec**




_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

**2. Atrial systole - 0.1 sec**

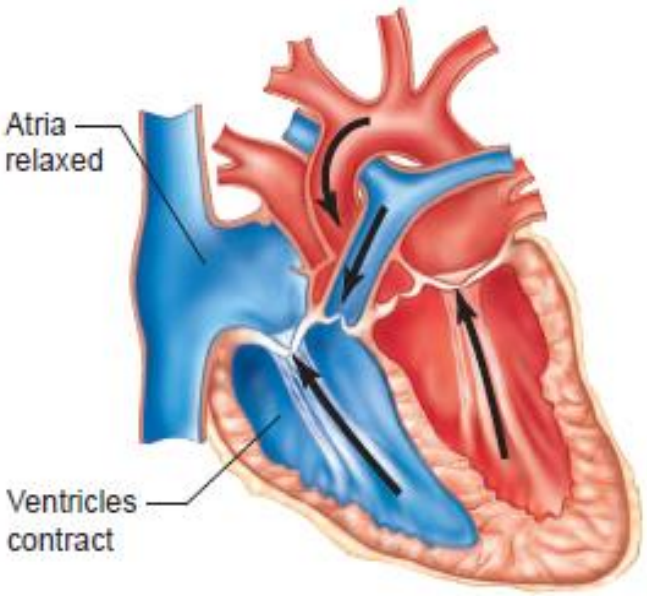



**3. Atrial diastole – 0.7 sec**

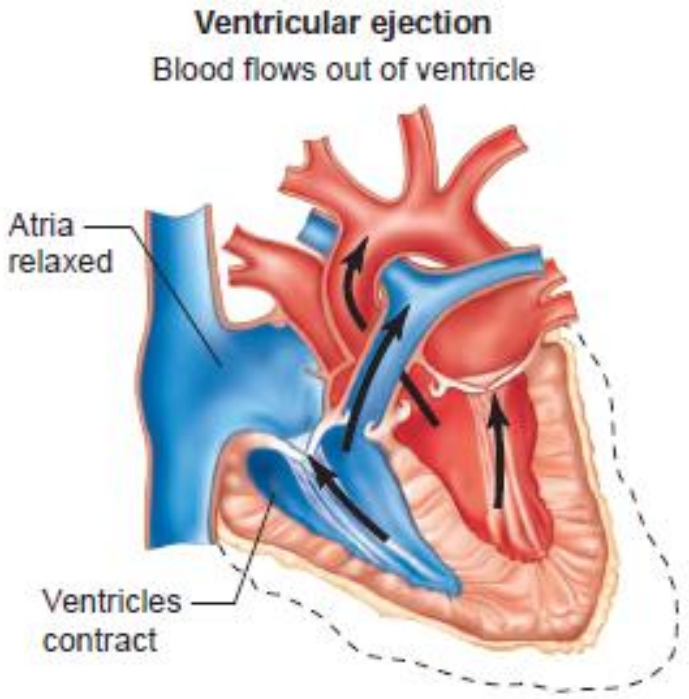
**4. Ventricular systole = 0.33 s <u>I. Period of tension = 0.08 s</u>**

***1) Phase of asynchronous contraction = 0.05 s***

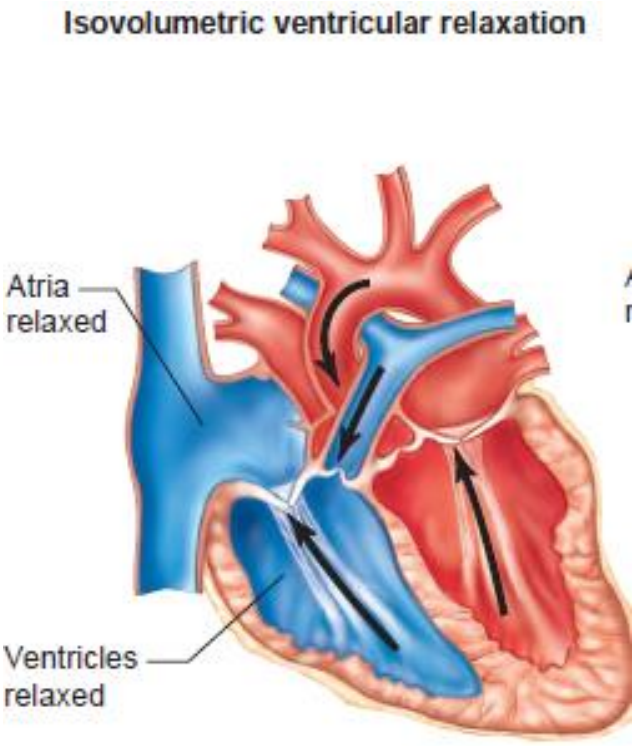
***2) Phase of isovolumetric contraction (IVC) = 0.03 s***



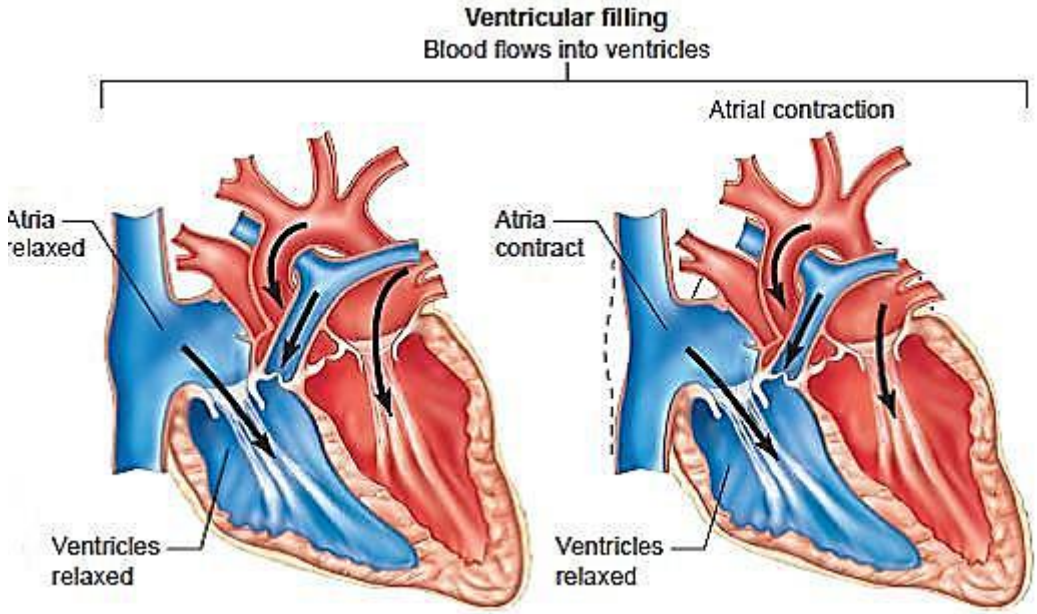
**5. Ventricular systole = 0.33 s <u>II. Period of ejection - 0.25 s</u>**




**6. Ventricular diastole = 0.47 s – Isovolumetric relaxation begins with protodiastolic period**



## 7. Ventricular diastole - Period of ventricular filling = 0.25 s




**Task 7.4**. *Events of cardiac cycle*

| Phase of CC | Valves | ECG | Heart sound |
|---|---|---|---|
| **AS** | | | |
| **IVC** | | | |
| **Rapid ejection** | | | |
| **Reduced ejection** | | | |
| **IVR** | | | |
| **Rapid filling** | | | |
| **Reduced filling** | | | |

**Task 7.5.** *Give definitions of Ventricular Volumes, normal values and formulas*

| Volume | Definition | Normal values | Formulas |
|---|---|---|---|
| **End-diastolic volume (EDV)** | | | |
| **End-systolic volume (ESV)** | | | |
| **Stroke volume (SV)** | | | |
| **Cardiac output (CO)** | | | |
| **Ejection Fraction (EF)** | | | |

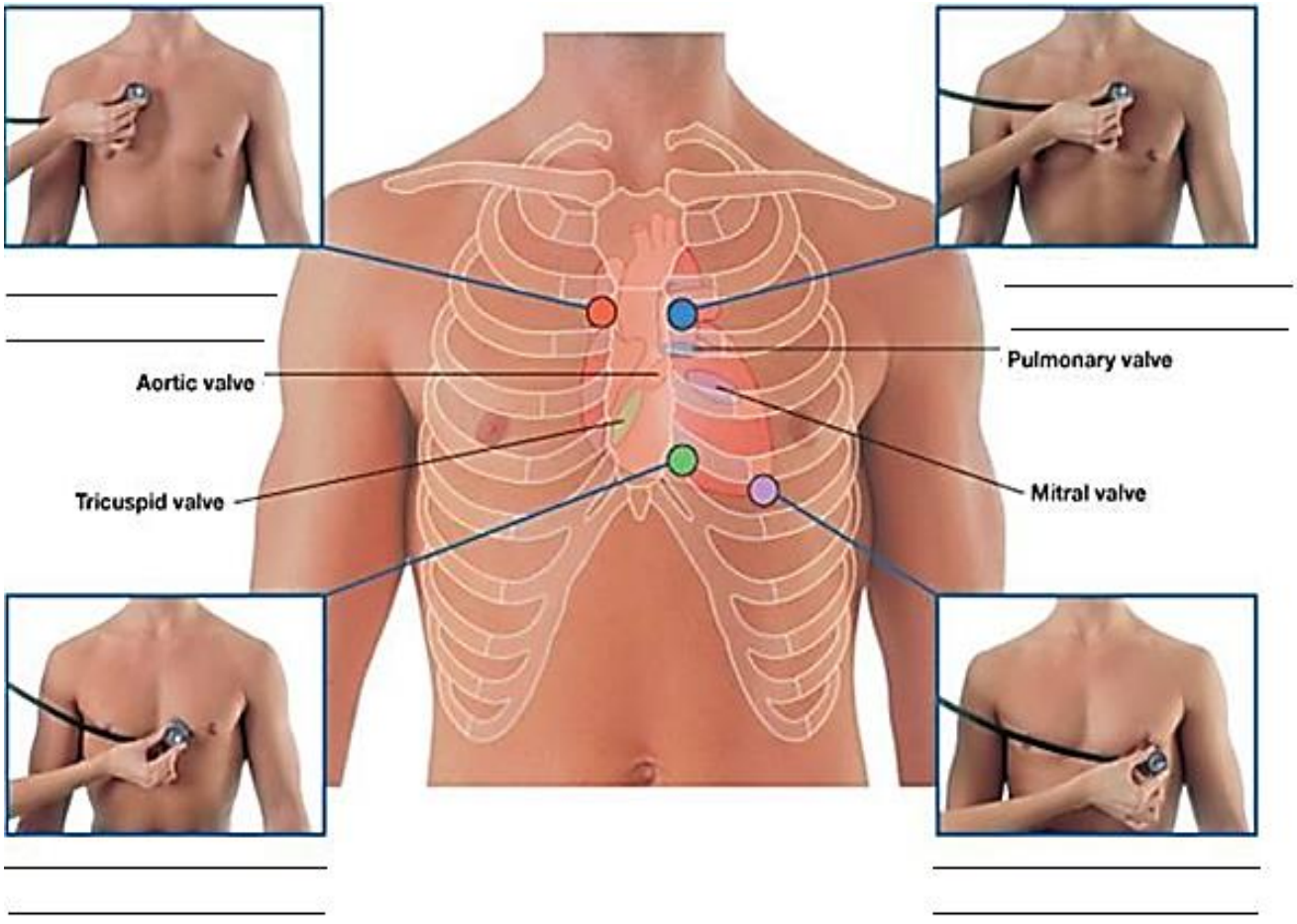
**Task 7.6.** *Fill in the table «Pressure differential»*

| Pressures in pulmonary circulation | | Pressures in systemic circulation | |
|---|---|---|---|
| Right ventricle | | Left ventricle | |
| Pulmonary artery | | Aorta | |
| Mean pulmonary art | | Mean arterial | |
| Capillary | | Capillary | |
| Pulmonary venous | | Peripheral veins | |
| Left atrium | | Right atrium | |
| Pressure gradient | | Pressure gradient | |

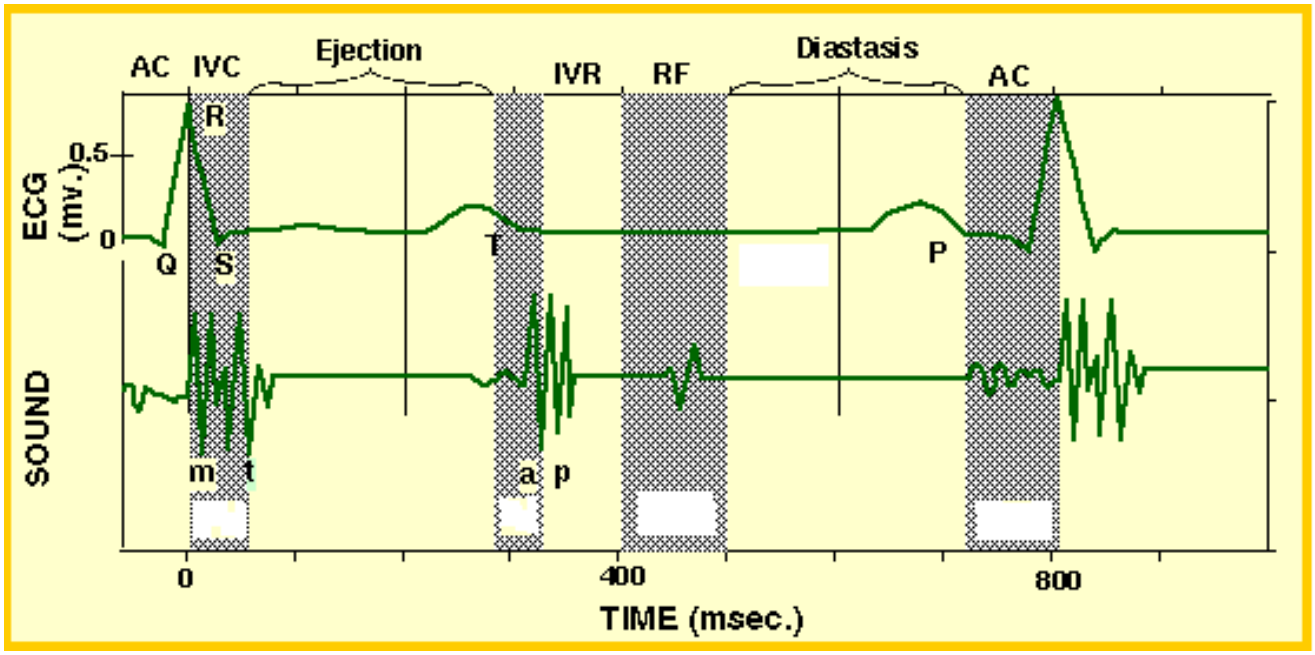
**Task 7.7.** *Define relationship of the heart sounds to heart pumping.*

| | ***Reasons of formation*** | ***Characteristics*** |
|---|---|---|
| **I heart sound** | | |
| **II heart sound** | | |
| **III heart sound** | | |
| **IV heart sound** | | |

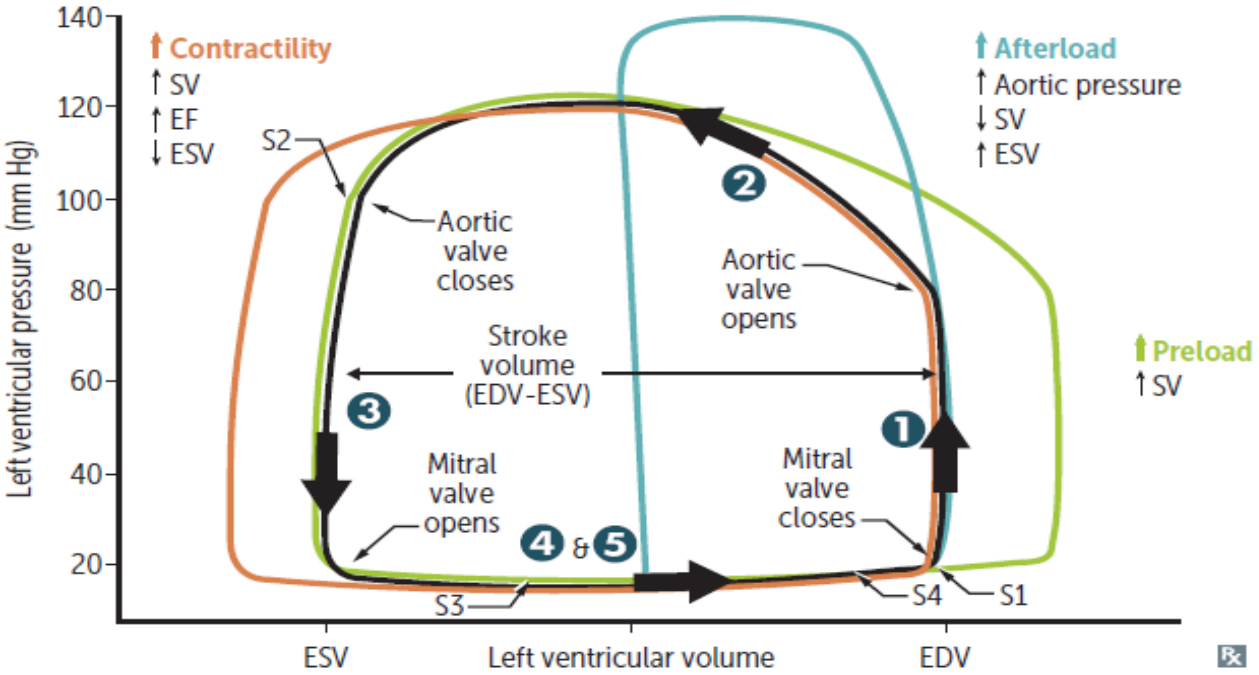
**Task 7.8.** *Define the chest surface areas for auscultation of normal heart sounds*.



**Task 7.9.** *Define relationship of phonocardiogram and electrocardiogram.*

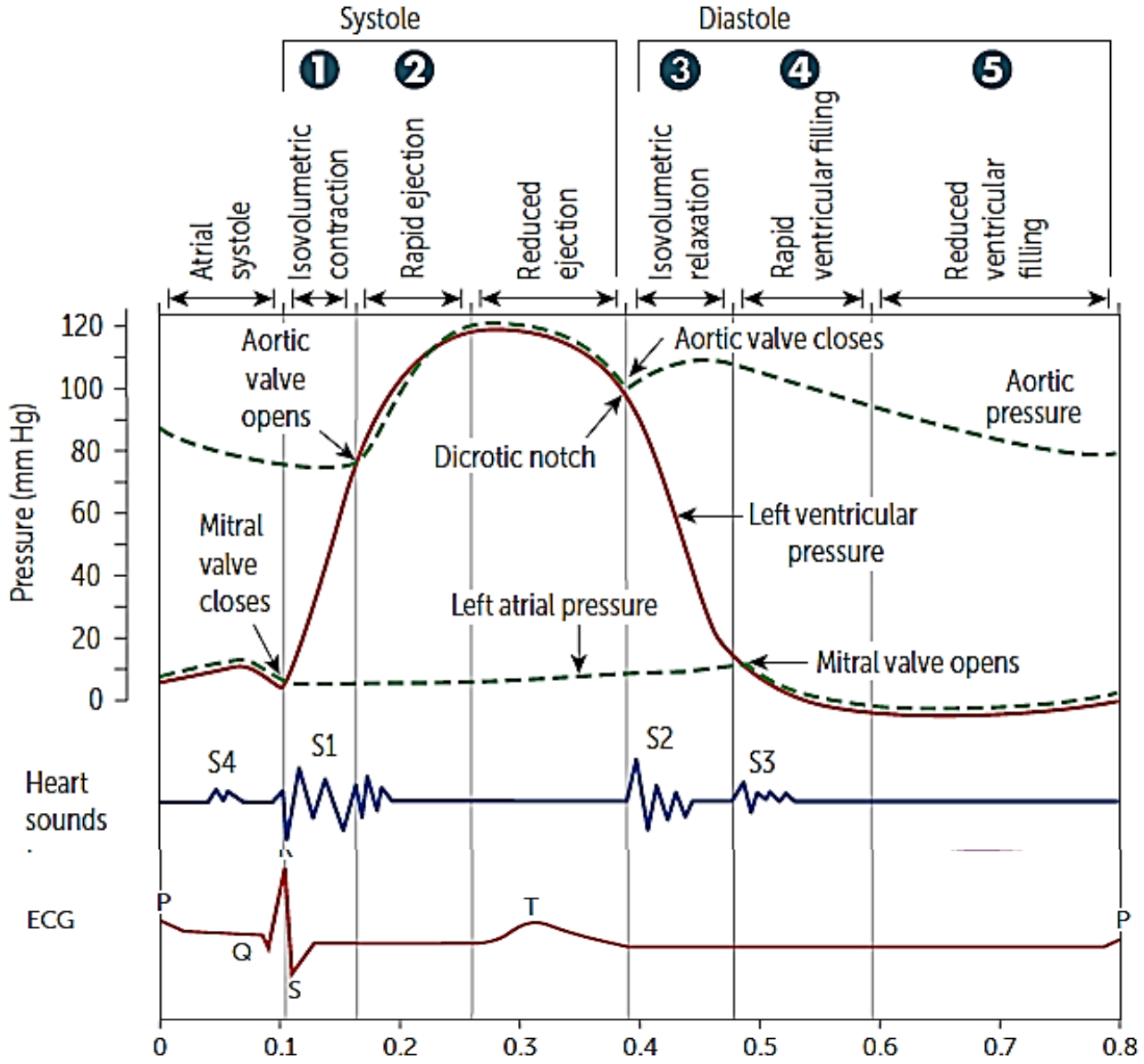



**Task 7.10.** *Name the phases of cardiac cycle indicated with numbers.*




1. _____
2. _____
3. _____
4. _____
5. _____

**Task 7.11.** *Learn the relationship between cardiac cycle events, phonocardiogram and electrocardiogram*



## PHYSIOLOGY OF THE VASCULAR SYSTEM

### 8. Give definition of hemodynamics

– _____
_____

**8.1.** *Functional classification of vessels. Fill in the table.*

| Functional type | Anatomical type | Physiological functions |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

**8.2.** *Compare arteries and veins. Fill in the table.*

| Feature | Arteries | Veins |
|---|---|---|
| **Direction of blood flow** | | |
| **Pressure** | | |
| **Wall thickness** | | |
| **Relative oxygen concentration** | | |
| **Valves** | | |

**Task 8.3.** *List main functions of endothelial cells.*

1. _____
_____
2. _____
_____
3. _____
_____
4. _____
_____
5. _____
_____

**Task 8.4.** *Memorize the indexes of hemodynamics*

- Velocity of blood flow (v)
- Volume Flow (Q)
- Total peripheral resistance (R)
- Compliance or capacitance (C)
- Arterial Pressure in the Systemic Circulation
- Venous Pressures in the Systemic Circulation
- Pressures in the Pulmonary Circulation

**Task 8.5.** *Give definition of volume velocity of blood flow and explain the dependence.*

$$Q = \frac{(P_1 - P_2)}{R} \qquad Q = \frac{\Delta P}{R}$$

*Define the parameters*
*Q is*_____
*ΔP is*_____
*R is*_____
*The dependence is following*
_____
_____
_____
_____
***How volume velocity of blood flow will be changed in case of***
*Vasoconstriction*_____
*Vasodilation* _____

**Task 8.6.** *Give definition of linear velocity of blood flow and explain the dependence.*

$$V = \frac{Q}{\pi r^2}$$

*Define the parameters:*
*V is*_____
*Q is*_____
$\pi r^2$ is_____

*The dependence is following*

_____
_____
_____
_____

the smallest vessel (aorta) → the V is _____
the largest vessel (*all* of the capillaries) → the V is _____ .

**Task 8.7.** *Give definition of peripheral vascular resistance and explain the dependence.*
**Poiseuille equation**

$$R = \frac{8l\eta}{\pi r^4}$$

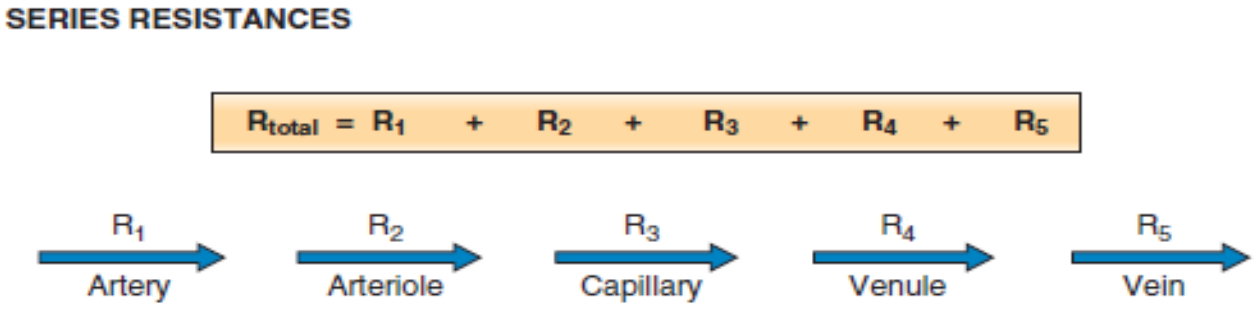
*Define the parameters:*
*R is*_____
*l is*_____
*η is*_____
$\pi r^4$ *is*_____
*The dependence is following:*

1. **R is _____ proportional to viscosity (η) of the blood;**
2. **R is _____ proportional to the length (l) of the blood vessel**
3. **R is _____ proportional to the fourth power of the radius ($r^4$) of the blood vessel**

- **if the radius of a blood vessel decreases by one half, resistance increases by _____-fold ($2^4$)!**

**Task 8.8. Resistances in the cardiovascular system can be arranged in series or in parallel producing different values for total resistance.**
*Explain the total resistance in Series arrangement*

_____
_____
*Series arrangement illustrates* _____

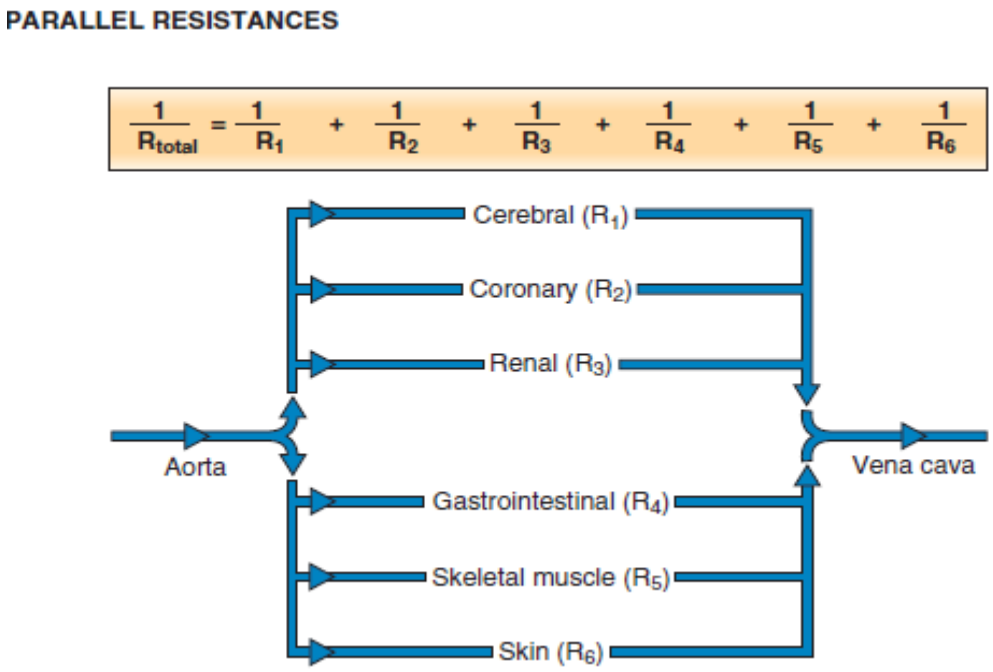


*And in parallel arrangement*

_____

_____

*parallel arrangement illustrates* _____




**Task 8.9.** *Laminar versus Turbulent blood Flow:*
*Laminar blood Flow*

_____

_____

*Turbulent blood Flow*

_____

_____

- *The Reynolds number is used to predict whether blood flow will be laminar or turbulent.*

$$N_R = \frac{\rho d v}{\eta}$$

**If NR is less than 2000 laminar flow**
**If NR is greater than 2000 → turbulent flow.**

Where:
NR = Reynolds number
ρ =
d =
v =
η =

***Name the possible causes of turbulent blood flow.***

1. _____
2. _____
3. _____
4. _____

**Task 8.10.** *Give definition of Compliance of Blood Vessels*

_____

_____

_____

***Describe the formula and dependence:***

$$C = V/P$$

- Where:
- C = Compliance or capacitance (mL/mm Hg)
- V =
- P =

The _____ the compliance of a vessel, the more volume it can hold at a given P.

- Compliance is essentially how easily a vessel is stretched.
- If a vessel is easily stretched, it is considered very compliant.
- The opposite is noncompliant or stiff.

*Compare compliance and blood volume of veins and arteries*

- The veins are most _____ and contain the unstressed volume (_____volume under _____ pressure).
- The arteries are _____ and contain the stressed volume (_____volume under _____pressure).
- The total volume of blood in the cardiovascular system is the sum of the unstressed volume plus the stressed volume (plus whatever volume is contained in the heart)

**Task 8.11. Pressures in the Cardiovascular System. Give definitions and define normal values of following types of arterial pressures.**

| Pressure | definition | normal values |
|---|---|---|
| ***SAP*** | | |
| ***DAP*** | | |
| ***PP***<br>***Formula:*** | | |
| ***MAP***<br>***Formula:*** | | |

**Task 8.12.** *Define factors affecting SAP, DAP, PP, MAP. Fill in the table.*

| | **SAP** | **DAP** | **PP** | ***MAP*** |
|---|---|---|---|---|
| ***1*** | | | | |
| ***2*** | | | | |
| ***3*** | | | | |

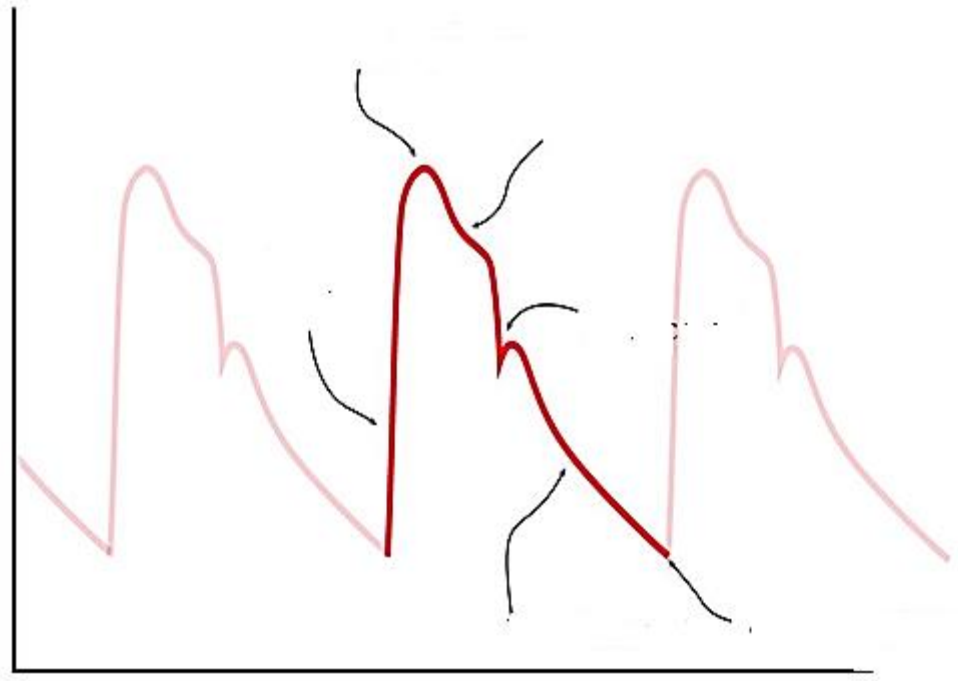
**Task 8.13.** *Explain why CO of the left heart is equal to CO of right hearts but pressure in pulmonary circulation is much lower? Prove your explanation with formula.*

_____
_____
_____

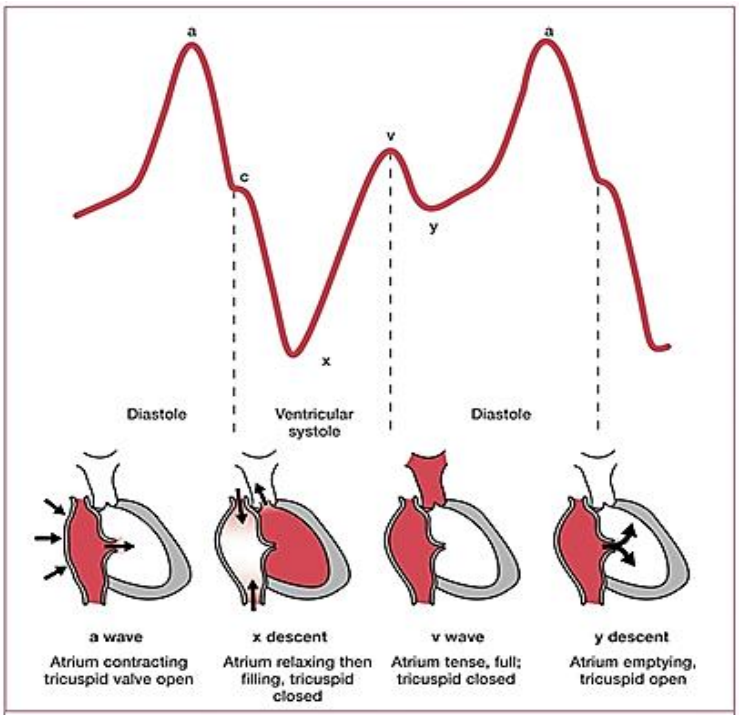
**Task 8.14. Define determinants of venous return.**

1. _____
2. _____
3. _____
4. _____
5. _____

**Task 8.15.** *Give definition of sphygmogram, mark the phases and pressure values. Label the picture.*



**Task 8.16. Jugular Venous Pulse – phlebogram.** *Mark the phases. Label the picture.*




**Task 8.17.** *Define the types of capillaries, their location and function.*

| ***Type*** | ***Location*** | ***Function*** |
|---|---|---|
| | | |
| | | |
| | | |

**Task 8.18.** *Define the statement of Starling equation*

$$J_v = K_f[(P_c - P_i) - (\pi_c - \pi_i)]$$

**where**

Jv = Fluid movement (mL/min)

Kf = _____(mL/min • mm Hg)

Pc = _____ (mm Hg)

Pi = _____ (mm Hg)

πc = _____ (mm Hg)

πi = _____ (mm Hg)

**Task 8.19.** *Give definition of filtration and reabsorption*

***Filtration is***

_____

_____

***Reabsorption is***

_____

_____

**Task 8.20.** *Complete the table.*

| Pressure | Definition | Normal value |
|---|---|---|
| **Kf, hydraulic conductance** | | |
| **Pc, capillary hydrostatic pressure** | | |
| **Pi, interstitial hydrostatic pressure** | | |
| **πc, capillary oncotic pressure** | | |
| **πi, interstitial oncotic pressure** | | |

**Use normal values of all types of pressure to calculate net filtration and net reabsorption pressure in arterial and venous parts of capillaries**

$$J_v = K_f[(P_c - P_i) - (\pi_c - \pi_i)]$$

net filtration pressure = _____

net reabsorption pressure= _____

**Task 8.21.** *List possible Causes of Edema Formation*

1. _____
2. _____
3. _____
4. _____

**Task 8.22.** *Give definition of arterial pulse*

_____
_____
_____

**Task 8.23.** *List the arterial pulse characteristics. Complete the table.*

| Index | Significance |
|---|---|
| **Rhythm.** | |
| **Frequency** | |
| **Tension** | |
| **Filling** | |
| **The form** | |

## 9. Regulation of heart activity

**Task 9.1.** *Study and memorize the mechanisms of cardiac activity regulation.*

| ***Neuronal regulation*** | | ***Humoral regulation*** |
|---|---|---|
| ***Intrinsic*** | ***Extrinsic*** | |
| **Myogenic**<br>– homeometric mechanism (Anrep's effect);<br>– heterometric mechanism (Frank-Starling law).<br>**Intracardiac peripheral reflexes**<br>– cardiostimulation;<br>– cardioinhibition | Autonomic nerves<br>Baroreceptors' reflex<br>Bainbridg reflex<br>Respiratory effect<br>Chemoreceptors' reflex | **Hormones**:<br>renin-angiotensin-aldosterone system (RAAS),<br>natriuretic peptide,<br>endothelin,<br>ADH,<br>thyroid hormones,<br>glucocorticoids,<br>mineralocorticoids,<br>catecholamines<br>**Ions**: $Na^+$, $K^+$, $Ca^{2+}$ |

### INTRINSIC MECHANISMS

**Task 9.2.** *Give definitions of preload and afterload and explain their role in heterometric and homeometric mechanisms*

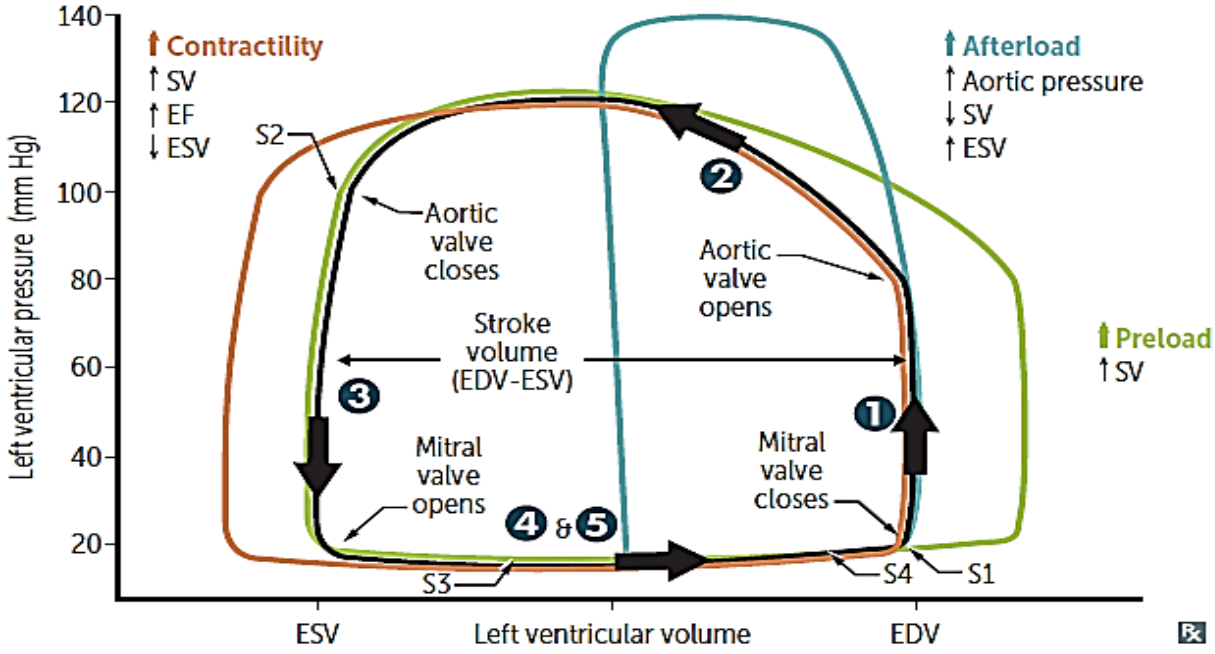
***Heterometric mechanism***

| **Preload** | **Frank-Starling law** |
|---|---|
| | |

***Homeometric mechanism***

| **Afterload** | **Phenomenon of Anrep** |
|---|---|
| | |

**Task 9.3.** *Learn how pressure-volume loop changes in cases of increased preload, afterload and contractility*




**Task 9.4.** *Complete the table «Intracardiac refle»"*

| receptors | Aff neuron | Nerve center | Eff neuron | Target cell |
|---|---|---|---|---|
| | | | | |

**Task 9.5.** *Brain Stem Cardiovascular Centers*

**Medullary cardiovascular center**

**Vasomotor area in ventrolateral medulla**

- Rostral ventrolateral nuclei,
- Inferior olivary complex

**Cardioinhibitory area**

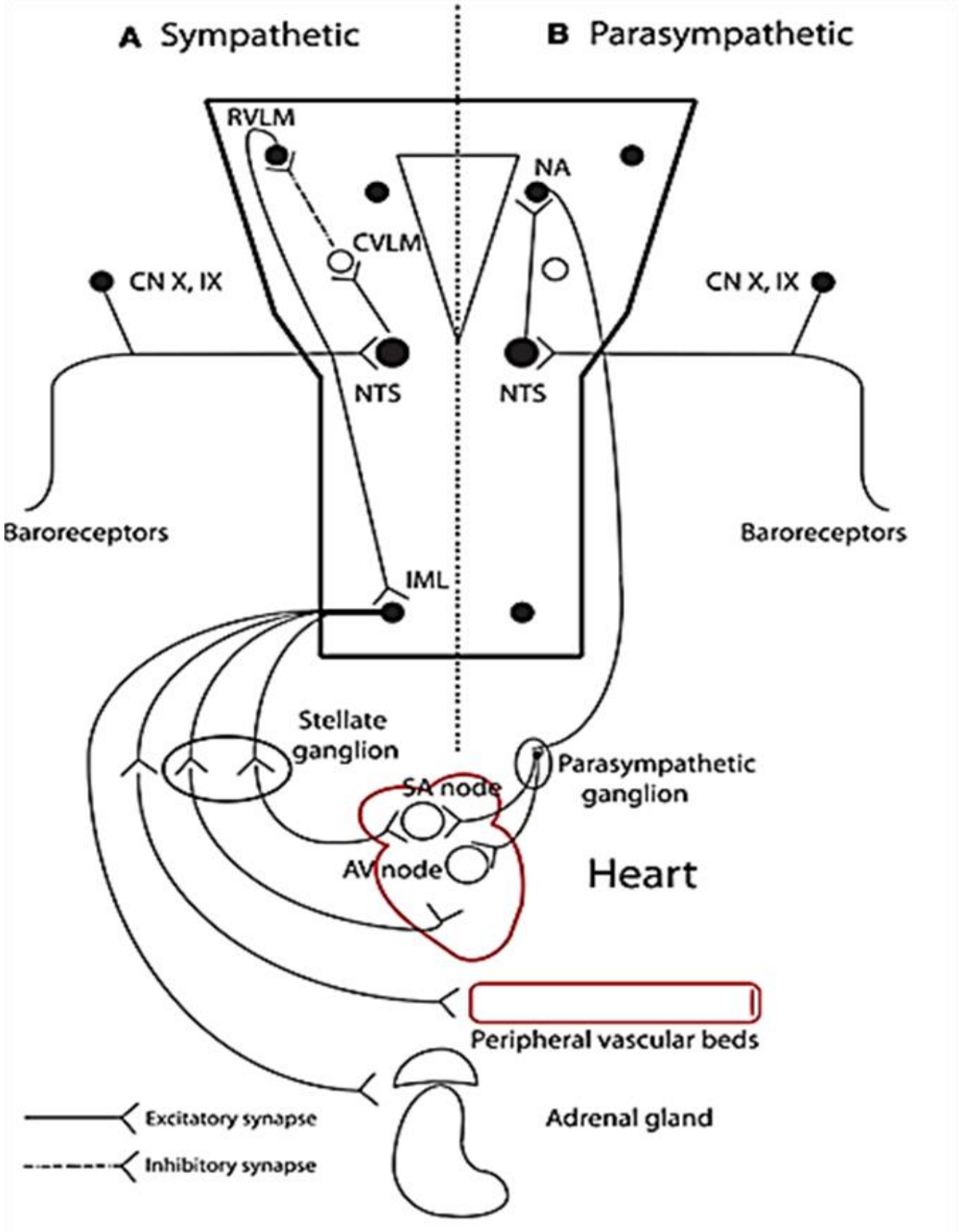
- Dorsal motor nucleus of n. vagus,
- Nucleus ambiguus

**Cardioacceleratory area**

Dorsal medulla

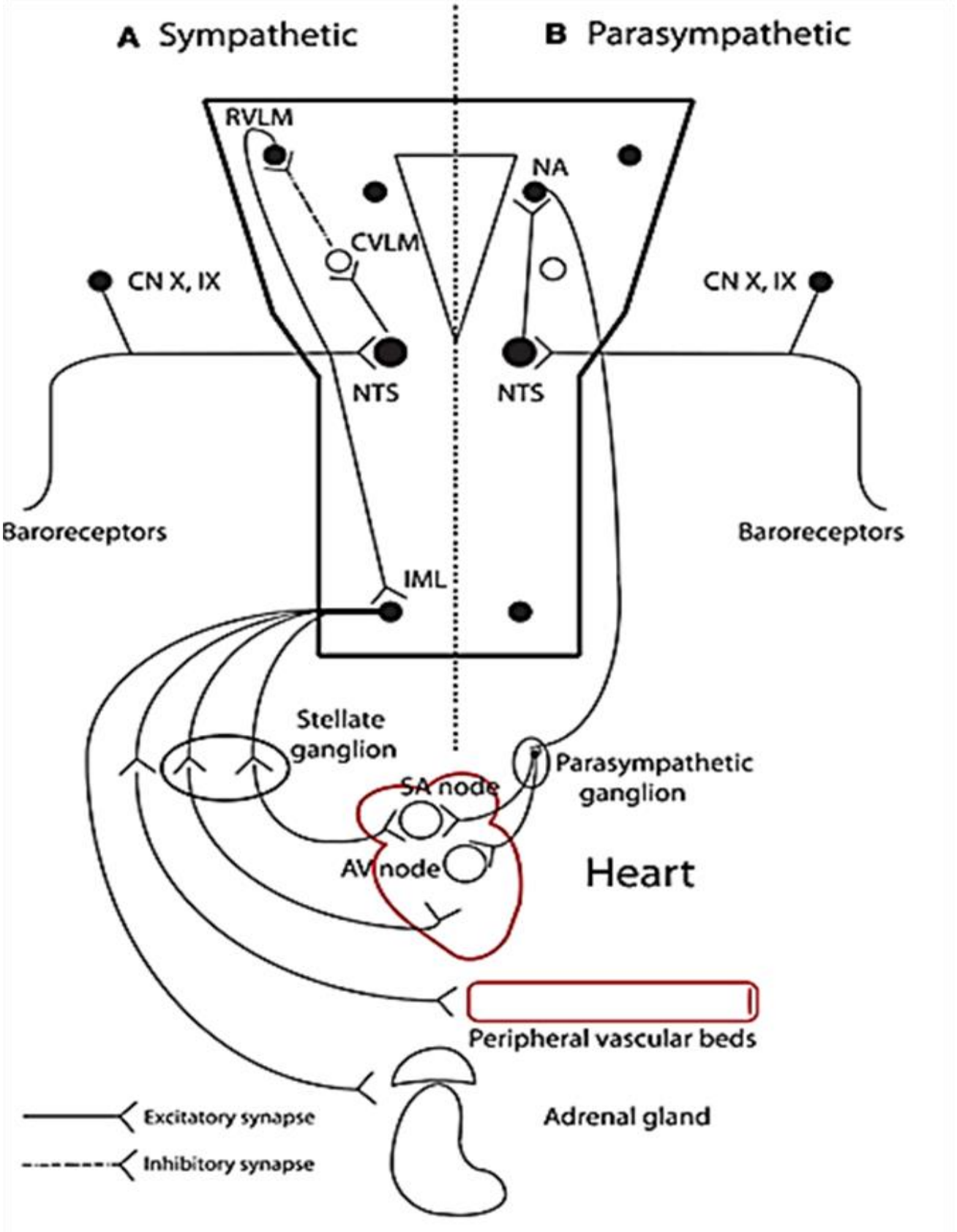
**Task 9.6**. *Cardiac acceleratory area pathway. Label the illustration with sequential numbers starting with baroreceptors -1*

**Define abbreviations.**

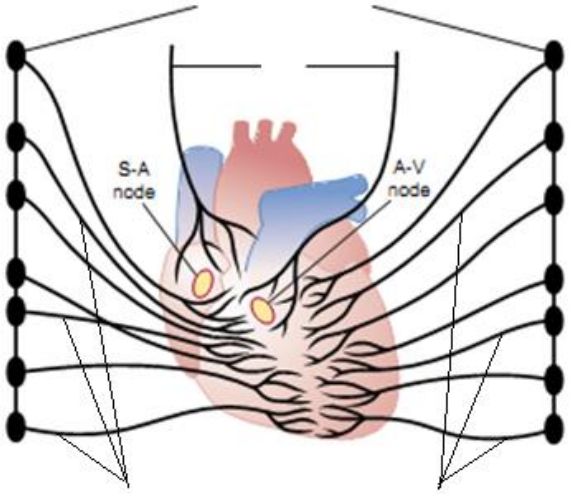


**Task 9.7.** *Cardiac inhibitory area pathway. Label the illustration with sequential numbers starting with baroreceptors -1*

**Define abbreviations.**



**Task 9.8.** *Define peculiarities of autonomic innervation of heart.*




**Sympathetic nerves innervate**

_____
_____
_____

**Right vagus nerve innerates**

_____
_____
_____

**Left vagus nerve innerates**

_____
_____
_____

**Task 9.9.** *Afferents to CardioVascular Center*

| **Afferent impulses from the higher centers** | |
|---|---|
| | |
| | |
| **Afferent from the venous side (Right Side of the heart):** | |
| | |
| | |
| **Afferent impulses from arterial side (carotid sinus and aortic arch):** | |
| | |
| | |
| | |
| | |
| **Afferent impulses from the respiratory system** | |
| | |
| **Afferent impulses from the other parts of the body** | |
| | |
| | |
| | |
| | |

**Task 9.10.** *Complete the table «Comparative characteristic of arterial and cardiopulmonary baroreceptors»*

| Feature | Arterial baroreceptors" (high pressure br) | Cardiopulmonary baroreceptors (low pressure br) |
|---|---|---|
| **Localization** | | |
| **Innervation** | | |
| **Function** | | |
| **Increase in firing rate** | | |

**Explain how does heart respond to an increased circulating blood volume.**
**Name 3 mechanisms involved in such response.**

1. **Define the role of cardiopulmonary baroreceptors**

_____
_____
_____
_____

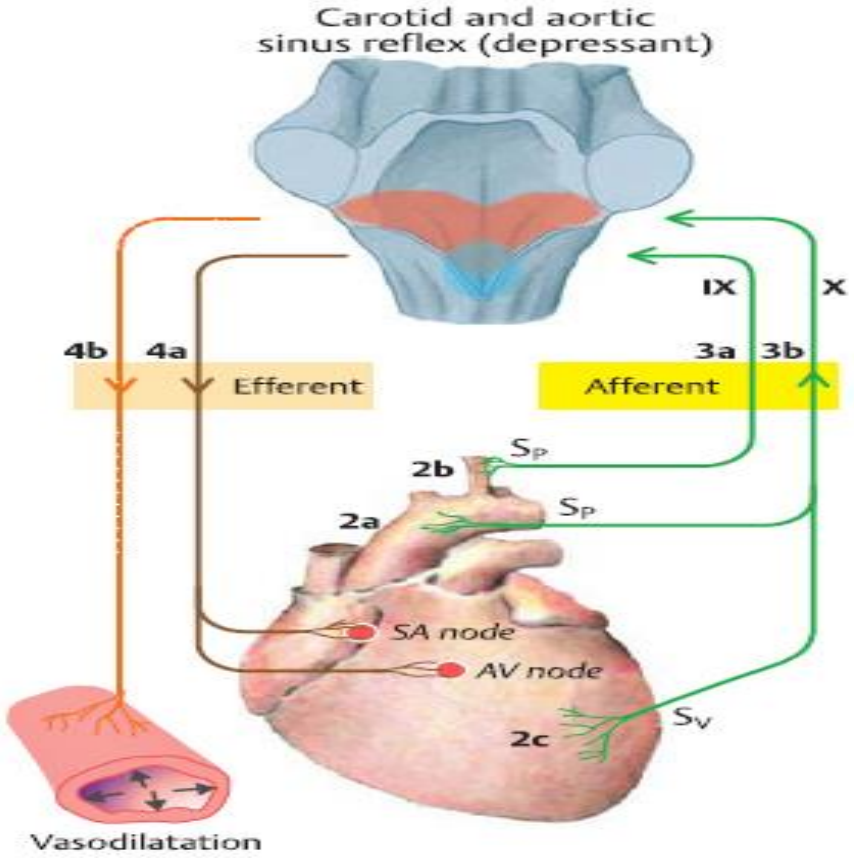
2. **Define the role of Bainbridge reflex**

_____
_____
_____
_____

3. **Define the role of Frank-Starling mechanism**

_____
_____
_____
_____

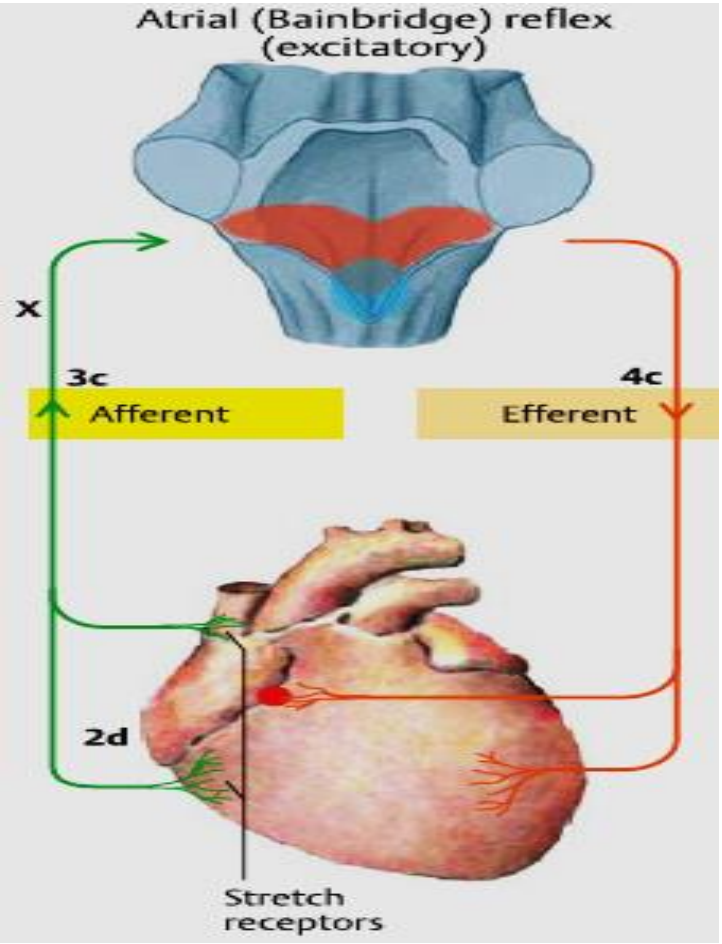
**Task 9.11.** *Describe the events of baroreceptor reflex*




| | |
|---|---|
| **Stimulus** | **Increased blood pressure** |
| **Receptors** | |
| **Aff nerves** | |
| **Nerve center** | |
| **Eff nerve** | |
| **Neurotransmitter** | |
| **Receptors** | |
| **Target cells** | |
| **Response reaction** | |

| | |
|---|---|
| **Stimulus** | **decreased blood pressure** |
| **Receptors** | |
| **Aff nerves** | |
| **Nerve center** | |
| **Eff nerve** | |
| **Neurotransmitter** | |
| **Receptors** | |
| **Target cells** | |
| **Response reaction** | |

**Task 9.12.** *Describe the events of Bainbridge reflex*



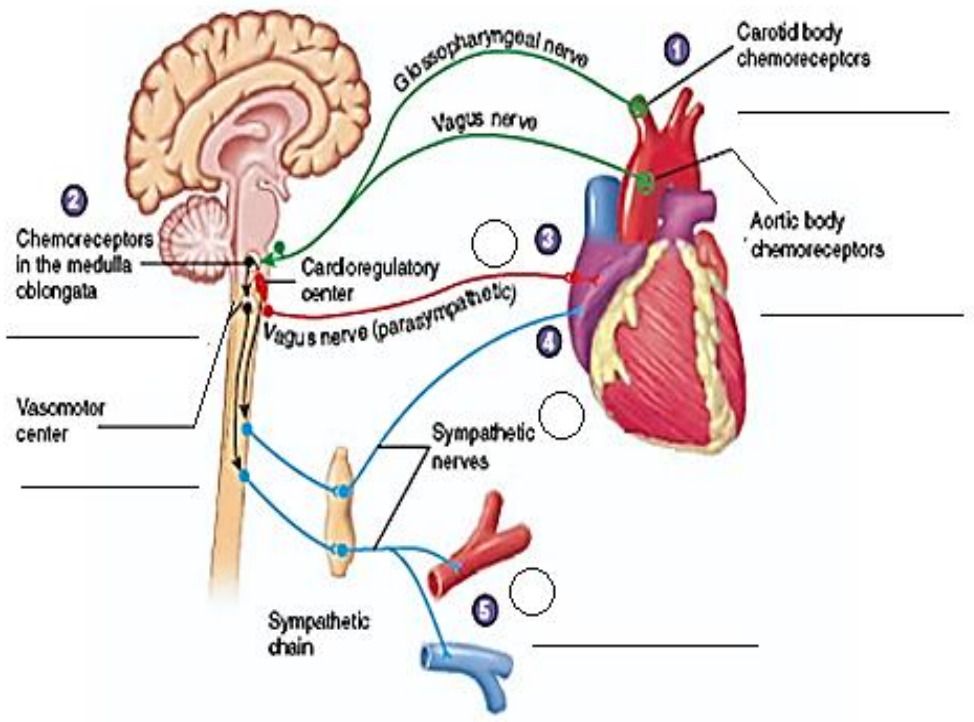

1. Venous return rises and atrial pressure rises
2. Receptors:_____
_____
_____
3. Aff nerve_____
_____
4. Nerve center _____
_____
_____
5. Eff nerves _____
_____
_____
6. Response:_____
_____
_____

**Task 9.13.** *Complete the table «Comparative characteristic of peripheral and central chemoreceptors»*

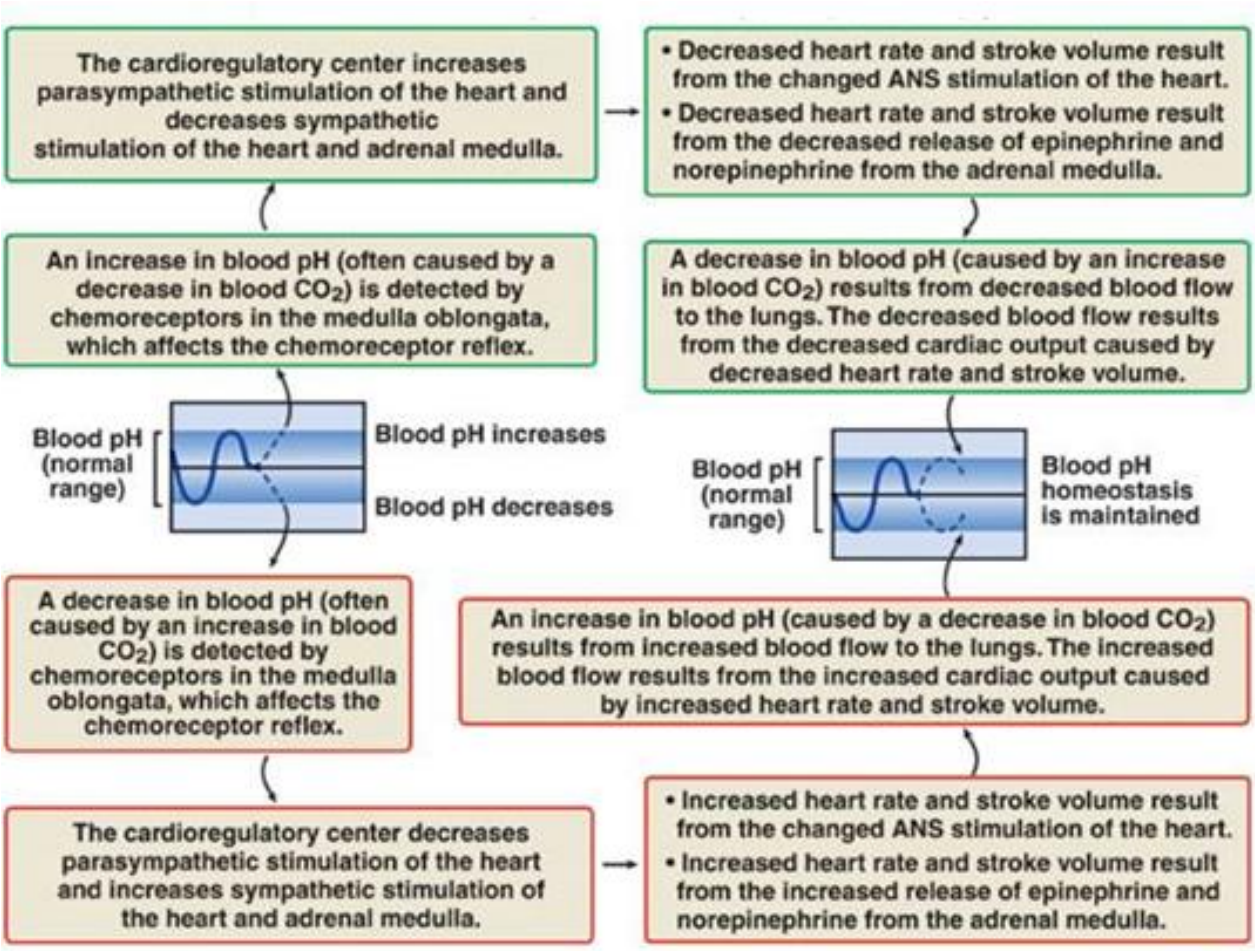
| Feature | Peripheral chemoreceptors” | Central chemoreceptors” |
|---|---|---|
| **Localization** | | |
| **Sensitivity** | | |
| **Function** | | |

**Task 9.14.** *Study the picture illustrating chemoreceptor reflex. Define 1) adequate stimuli for peripheral and central receptors; 2) direction of excitation conduction and 3) effects («+ » or «−») to the target organs.*

1. Chemoreceptors in the carotid and aortic bodies monitor blood $O_2$, $CO_2$, and pH.
2. Chemoreceptors in the medulla oblongata monitor blood $CO_2$ and pH.
3. Decreased blood $O_2$, increased $CO_2$, and decreased pH decrease parasympathetic stimulation of the heart, which increases the heart rate.
4. Decrease blood $O_2$, increased $CO_2$, and decreased pH increase sympathetic stimulation of the heart, which increases the heart rate and stroke volume.
5. Increased sympathetic stimulation of blood vessels increases vasoconstriction.



**Task 9.15.** *Memorize the mechanism of cardiac activity regulation in case of pH changes.*




**Task 9.16.** *Facts about HR. complete the statements.*

- In normal adults the average HR at rest is approximately _____ bpm**;**
- During sleep the HR _____by _____ beats/min,
- during emotional excitement or muscular activity – above _____ beats/min.
- In well-trained athletes at rest - about _____ bpm.
- **The SA node is under the tonic influence of both SANS and PANS.**
- **parasympathetic tone predominates in healthy, resting individuals.**
- Blockade of parasympathetic effects by administration of atropine (a muscarinic receptor antagonist) usually _____HR,
- blockade of sympathetic effects by administration of propranolol (a β-adrenergic receptor antagonist) usually _____HR slightly
- When both divisions of the autonomic nervous system are blocked, the HR of young adults averages about _____ bpm –intrinsic heart rate.

**Task 9.17.** *Effects of sympathetic and parasympathetic regulation to myocardium*

| Parasympathetic | | effect | sympathetic | |
|---|---|---|---|---|
| | | **bathmotropic** | | |
| | | **dromotropic** | | |
| | | **inotropic** | | |
| | | **chronotropic** | | |

**Task 9.18.** *Explain positive and negative chronotropic effects to myocardium. Fill in the table.*

| Structure | Positive chronotropic effect | Negative chronotropic effect |
|---|---|---|
| Autonomic nerve | | |
| Neurotransmitter | | |
| Target cells | | |
| Receptors | | |
| Mechanism | | |

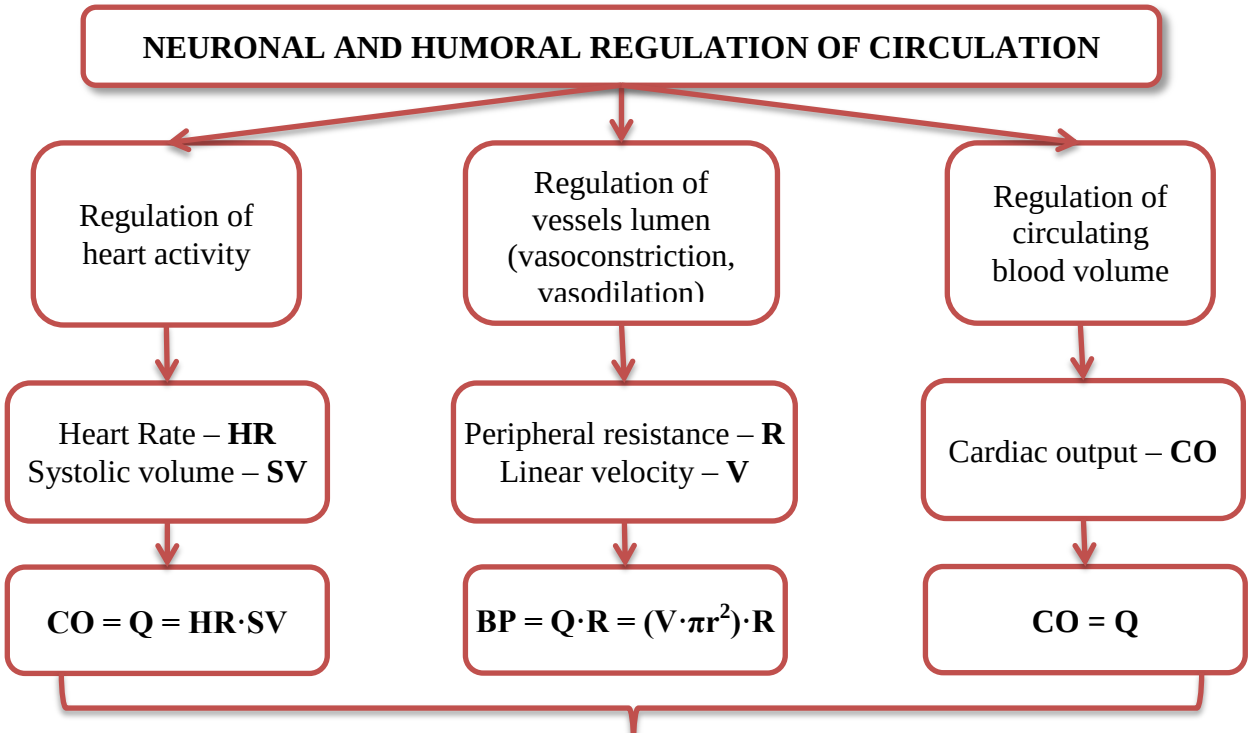
**Task 9.19.** *Explain positive and negative dromotropic effects to myocardium. Fill in the table.*

| Structure | Positive dromotropic effect | Negative dromotropic effect |
|---|---|---|
| Autonomic nerve | | |
| Neurotransmitter | | |
| Target cells | | |
| Receptors | | |
| Mechanism | | |

**Task 9.20.** *Explain positive and negative inotropic effects to myocardium. Fill in the table.*

| structure | positive inotropic effect | negative inotropic effect |
|---|---|---|
| Autonomic nerve | | |
| Neurotransmitter | | |
| Target cells | | |
| Receptors | | |
| mechanism | | |

## 10. Regulation of circulation




***Correspondence of blood flow to the needs of organs and systems***

**Task 10.1.** *Regulation of blood flow to the organs*

The smooth muscle tone of the vascular wall changes in response to
1. *local* stimuli (autoregulation)
2. *hormonal s*ignals
3. *neuronal signals*

| Feature | Autoregulation | Humoral signals | Neuronal signals |
|---|---|---|---|
| **Mechanism of regulation and components** | | | |

**Task 10.2.**

| Mechanism | Vasoconstriction | Vasodilation |
|---|---|---|
| **Neuronal signals (division of ANS, neurotransmitters, receptors)** | | |
| **Local (myogenic and humoral agents)** | | |
| **Hormonal and metabolites** | | |

**Task 10.3**. *Draw the scheme of Renin-Angiotensin-Aldosterone System*

## EFFECTS OF SYMPATHETIC AND PARASYMPATHETIC PATHWAYS ON THE CARDIOVASCULAR SYSTEM

| EFFECTOR RESPONSE | ANATOMIC PATHWAY | NEURO-TRANSMITTER | RECEPTOR |
|---|---|---|---|
| **Tachycardia** | Sympathetic | Norepinephrine | $\beta_1$ on cardiac pacemaker |
| **Bradycardia** | Parasympathetic | Acetylcholine | $M_2$ on cardiac pacemaker |
| **Increase cardiac contractility** | Sympathetic | Norepinephrine | $\beta_1$ on cardiac myocyte |
| **Decrease cardiac contractility** | Parasympathetic | Acetylcholine | $M_2$ on cardiac myocyte |
| **Vasoconstriction in most blood vessels (skin, kidney)** | Sympathetic | Norepinephrine | $\alpha_1$ on VSMCs |
| **Vasodilation in most blood vessels (muscles, myocardium)** | Adrenal medulla | Epinephrine | $\beta_2$ on VSMCs |
| **Vasodilation in "fight or flight" response** | Sympathetic | Acetylcholine | $M_2$ receptor |
| **Vasodilation in blood vessels of salivary glands and erectile blood vessels** | Parasympathetic | Acetylcholine | $M_2$ receptor |

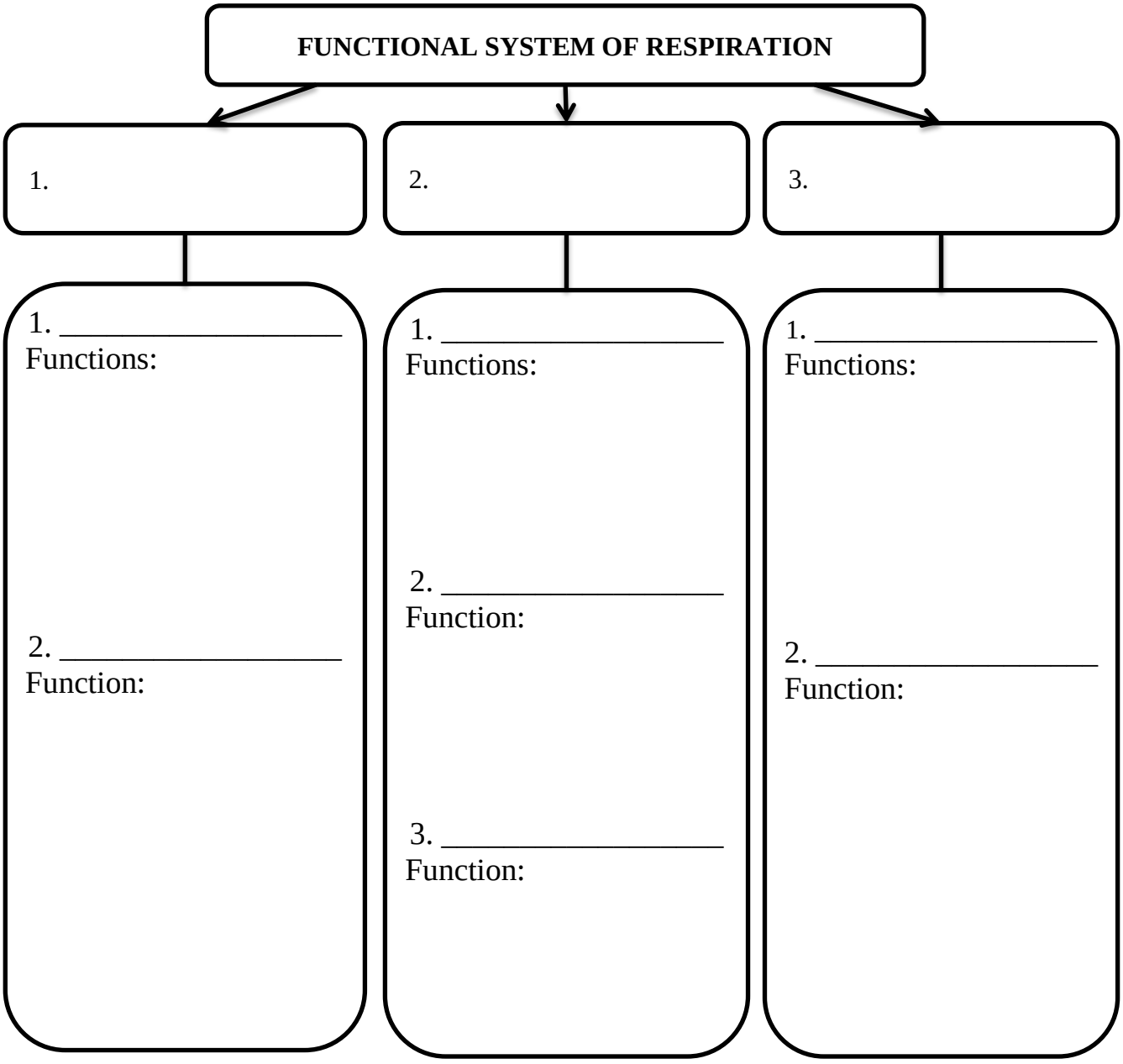
## PHYSIOLOGY OF RESPIRATION

11. GENERAL CHARACTERISTICS OF SYSTEM OF RESPIRATION.
EXTERNAL RESPIRATION.

**Task 11.1.** *Give definition of respiration.*
*Respiration is*

_____
_____
_____

**Task 11.2.** *Complete the scheme «Functional system of respiration» and define functions of all of its components.*



**Task 11.3.** *List the functions of respiratory system:*

- _____
- _____
- _____
- _____

**Task 11.4.** *List non respiratory functions of lungs:*

- _____
- _____
- _____
- _____
- _____
- _____
- _____
- _____
- _____
- _____
- _____
- _____

**Task 11.5.** *Complete the schemes showing the structure of cough and sneezing reflexes.*

***1) Cough reflex***

| Stimulus | Receptors | Afferent nerve | Nerve center | Efferent nerve | Target organ | Response |
|---|---|---|---|---|---|---|
| | | | | | | |

***2) Sneezing reflex***

| Stimulus | Receptors | Afferent nerve | Nerve center | Efferent nerve | Target organ | Response |
|---|---|---|---|---|---|---|
| | | | | | | |

**Task 11.6.** *Respiration occurs in **3 stages** and **5 processes**. Name them and explain the events of everyone.*

**I.** _____**:**

*1)* _____

*2)* _____

**II.** _____**:**

*3)* _____

*4)* _____

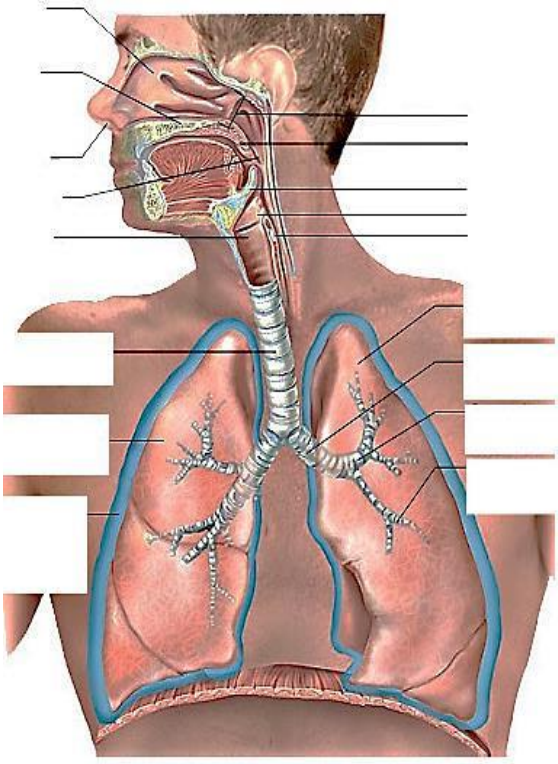
**III.** _____**:**

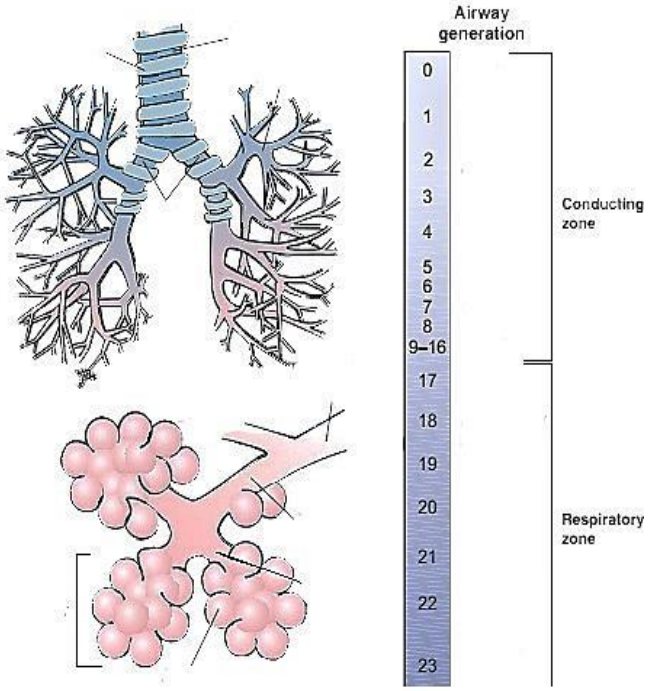
*5)* _____

**Task 11.7.** *Complete the table «Respiratory chain of oxygen and carbon dioxide»*

| Oxygen respiratory chain | Carbon dioxide respiratory chain |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |

**Task 11.8.** *Fill the illustration «Functional anatomy of respiratory system»*





**Task 11.9. List anatomical structures belong to conducting zone and respiratory zone.**

| Feature | Conducting zone | Respiratory zone |
|---|---|---|
| **structures** | | |
| **function** | | |
| **innervarion** | | |

**Task 11.10.** *List the types of alveolar cells and define their functions:*

1. _____

Function:_____

2. _____

Function:_____

3. _____

Function:_____

**Task 11.11.** *Define pleural cavity and its functions*

_____

_____

_____

_____

*Functions:*

*1.* _____

*2.* _____

*3.* _____

**Task 11.12.** *List the physical properties of lungs which determine pulmonary ventilation:*

- _____
- _____
- _____

**Task 11.13.** *Explain the significance and dependence of lungs' compliance.*
*Compliance is* _____
_____
_____
_____

$C = \frac{\Delta V}{\Delta P}$ ; where C – compliance
V –
P –

**Task 11.14.** *Give the definition of elasticity of lungs and define its importance.*

*Elasticity is* _____
_____
_____
_____

**Define how compliance and tendency to collapse change in following lungs pathologies:**

1. *Emphysem:*_____
   _____
2. *Fibrosis:*_____
   _____

**Task 11.15.** *Explain the genesis of surface tension of the alveoli:*
_____
_____
_____

*Describe formula representing collapsing pressure and dependence (***Laplace's law)**

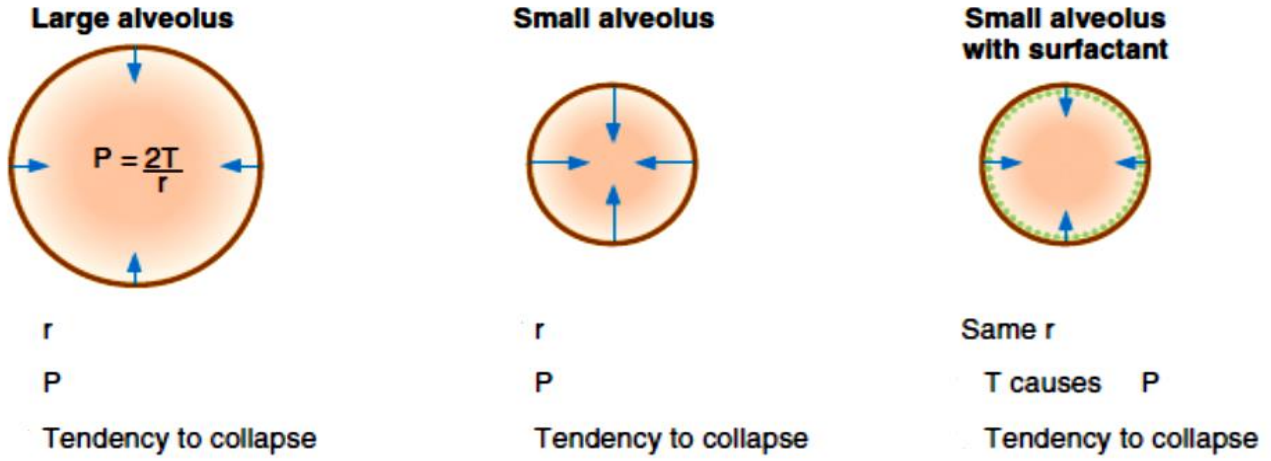
$$P = \frac{2T}{r}$$

*where:*
P = collapsing pressure on alveolus (or pressure required to keep alveolus open) [dynes/cm$^2$]
T = _____ (dynes/cm)
r = _____ (cm)

***Compare collapsing pressure in small and large alveoli. Fill in the illustration.***

*small alveoli*_____

*large alveoli*_____




**Task 11.16.** *Give the definition of surfactant and list its functions.*

| Feature | Surfactant |
|---|---|
| ***Function*** | |
| ***Mechanism of effect*** | |
| ***Cells synthesizing*** | |
| ***Term of sufficient synthesis*** | |
| ***Diagnostic sign of mature synthesis*** | |
| ***Pathology of deficiency*** | |

**Task 11.17. Give definitions of following terminology.**

**Alveolar pressure**

_____

_____

**Pleural pressure**

_____

**Transpulmonary pressure**

_____

_____

_____

**Task 11.18.** *Define the values of $P_{AL}$, $P_{pl}$ and $P_L$ relating to the phase of respiration.*

| | **$P_{AL}$,** mmHg | **$P_{pl}$,** mmHg | **$P_L$,** mmHg |
|---|---|---|---|
| Quite inspiration | | | |
| Forced inspiration | | | |
| Quite expiration | | | |
| Forced expiration | | | |

**Task 11.19.** *Explain the Relationships between pressure, airflow, and resistance*

$$Q = \frac{\Delta P}{R}$$

*where:*

Q = airflow (mL/min or L/min)

ΔP = _____ (cm $H_2O$)

R = _____ (cm $H_2O$/L/min)

**Make conclusion:**

_____

_____

**the higher the airway resistance, the _____ the airflow**

**Task 11.20.** *Resistance of the airways. Name factors affecting resistance and make conclusion.*

$$R = \frac{8\eta l}{\pi r^4}$$

**Poiseuille's law,** *where:*

**R = resistance,**

**η = _____**

**l = _____**

**r = _____**

**Name the factors that change airway resistance:**

1. Parasympathetic stimulation

_____

_____

2. Sympathetic stimulation

_____

_____

3. Viscosity or density of inspired gas

_____

**Task 11.21.** *The movement of air into and out of the lungs depends upon several factors. Name them and show their significance.*

1. **Boyle's law** – _____
_____
2. **Gradient of $P_{in}$ and $P_{out}$:**

- **$P_{in} = P_{out}$** _____
_____
- **$P_{in} \geq P_{out}$** _____
_____
- **$P_{in} \leq P_{out}$** _____
_____

**Task 11.22.** *Respiratory muscles and their innervation*

| Phase of respiration | Respiratory muscles | Innervation |
|---|---|---|
| **Quiet inspiration** | | |
| | | |
| **Quiet expiration** | | |
| **Forced inspiration** | | |
| | | |
| | | |
| | | |
| **Forced expiration** | | |
| | | |

**Task 11.23.** *Rest is a period between breathing cycles when the diaphragm is at its equilibrium position. Fill in the table.*

| Feature | Explanation |
|---|---|
| **P alvealar** | |
| **P pleural** | |
| **P transpulmonary** | |
| **Airflow** | |
| **Respiratory muscles state** | |
| **Volume of air in lungs** | |

**Task 11.24.** *Describe events during Inspiration. Fill in the table.*

| Feature | Explanation |
|---|---|
| **Volume of lungs** | |
| **P alvealar** | |
| **P pleural** | |
| **P transpulmonary** | |
| **Airflow** | |
| **Respiratory muscles state** | |
| **Volume of air in lungs** | |

**Task 11.25.** *Describe events during expiration. Fill in the table.*

| Feature | Explanation |
|---|---|
| **Volume of lungs** | |
| **P alvealar** | |
| **P pleural** | |
| **P transpulmonary** | |
| **Airflow** | |
| **Respiratory muscles state** | |
| **Volume of air in lungs** | |

**Task 11.26.** *Give the definition of following methods of pulmonary function examination and name the purposes of their usage.*

***1. Spirography*** *is* _____
_____
_____

***Spirogram*** *is* _____
_____
_____

***2. Pneumotachography*** *is* _____
_____
_____

**Task 11.27.** *Complete the table «Main indexes of external respiration»*

| № | Index | Definition | Normal value |
|---|---|---|---|
| **1** | | | |
| **2** | | | |
| **3** | | | |
| **4** | | | |
| **5** | | | |
| **6** | | | |
| **7** | | | |
| **8** | | | |
| **9** | | | |
| **10** | | | |

**Task 11.28.** *Give the definition of dead space.*
**Anatomic dead space** is _____
_____
_____
**Physiologic dead space** is _____
_____
_____

**Task 11.29.** *There are 2 types of ventilation disorders that can cause problems with air movement in and out of lungs. Name them and briefly explain their mechanisms by filling the table.*

| Obstructive disorders | Restrictive disorders |
|---|---|
| | |

## 12. GASES EXCHANGE AND TRANSPORT OF GASES BY BLOOD

**Task 12.1.** *Gas laws of respiratory physiology*

| Gas laws | Explanation |
|---|---|
| **Boyle's Law** | |
| **Charles' Law** | |
| **Dalton's Law** | |
| **Henry's Law** | |
| **Fick's Law** | |

**Task 12.2.** *Define the Dalton's Law of Partial Pressures. Describe the formula.*

$$Px = (PB - PH_2O) \times F$$

PX = Partial pressure of gas (mm Hg)
PB = _____ (mm Hg)
$PH_2O$ = _____ at 37 °C
F = _____

*Give the definition of partial pressure of gas in gas mixture.*

**Partial pressure of gas** is _____
_____
_____

- **Calculate $PO_2$ in:**
- dry inspired air, - $PO_2$ =
- Humidified tracheal air - $PO_2$ =
- alveolar air - $PO_2$ =

**Task 12.3.** *Define the law of Diffusion of Gases - Fick's Law. Describe the formula.*

$$\dot{V}x = \frac{DA\Delta P}{\Delta x}$$

**VX = Volume of gas transferred per unit time**
**D** = _____
**A** = _____
**ΔP** = _____
**Δx** = _____
**Make conclusion:**
_____
_____
_____

**Task 12.4.** *Fill the table "Partial pressures of individual respiratory gases"*

| *Gas* | *Inspired air* | | *Alveolar air* | | *Expired air* | |
|---|---|---|---|---|---|---|
| | *%* | *mm Hg* | *%* | *mm Hg* | *%* | *mm Hg* |
| **$O_2$** | | | | | | |
| **$CO_2$** | | | | | | |
| **$N_2$** | | | | | | |
| **$H_2O$** | | | | | | |

**Task 12.5.** *Define the factors affecting diffusion of gases*

1. **Partial pressures of oxygen and carbon dioxide are the driving force for diffusion of these gases** across the respiratory membrane. Fill the table and show by arrows the direction of $O_2$ and $CO_2$ diffusion.

| **Gas** | ***In the alveoli*** | | ***In the tissue*** | |
|---|---|---|---|---|
| | **Alveolar air** | **Venous blood** | **Arterial blood** | **ECF** |
| **$O_2$** | | | | |
| **$CO_2$** | | | | |

2. **lung diffusing capacity (DL) which combines several factors. List them and define dependence.**

- _____
- _____
- _____

***Define the change in DL in following diseases:***

- In **emphysema –** _____.
- In **fibrosis** or **pulmonary edema –**

_____

- In **anemia –** _____
- During **exercise –** _____

**Task 12.6.** *List the layers of respiratory membrane:*

- _____
- _____
- _____
- _____
- _____
- _____
- _____

**Task 12.7.** *List the forms of oxygen transport:*

- _____
- _____
- the solubility of $O_2$ in blood is 0.003 mL $O_2$/100 mL blood/mm Hg.
- Calculate the concentration of dissolved $O_2$ in 100 ml of oxygenated blood.
- _____
- Dissolved $O_2$ is free in solution and accounts for approximately _____**% of the total $O_2$ content of blood.**
- The remaining _____ **% of the total $O_2$ content of blood** is reversibly bound to hemoglobin inside the RBC.
- The **$O_2$-binding capacity** is the ***maximum*** **amount of $O_2$**

**1 g of HbA can bind _____ mL $O_2$**

At the concentration of HbA in blood is 15 g/100 mL the $O_2$-binding capacity of blood is _____ mL $O_2$/100 mL blood

Show the way of calculation.

_____

- The **$O_2$ content** is the actual amount of $O_2$ per volume of blood. Define the formula.

**Oxygen content = _____**

The amount of $O_2$ delivered to tissues is determined by **blood flow and the $O_2$ content of blood**. Define the formula.

**Oxygen delivery** = _____

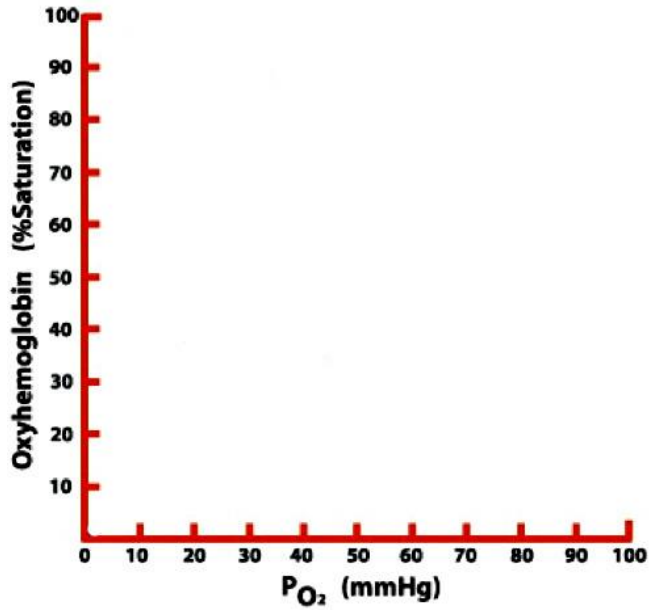
**Task 12.8. Why $O_2$ is loaded into pulmonary capillary blood from alveolar gas and unloaded from systemic capillaries into the tissues?**

_____
_____
_____
_____
_____
_____

**Task 12.9.** *Draw the diagram «Oxyhemoglobin dissociation curve». Mark the percent of oxygen saturation when partial pressure of oxygen is:*

- ***$Po_2$ = 40 mm hg***
- ***$Po_2$ = 60 mm hg***
- ***$Po_2$ = 100 mm hg***

*Draw the shifts of oxyhemoglobin dissociation curve to the left and to the right and list the conditions when these shifts occur.*




**Left shift**
**(_____ affinity)**

- _____
- _____
- _____
- _____

**Right shift**
**(_____ affinity)**

- _____
- _____
- _____
- _____

**Task 12.10.** *Define the factors that provide $HbO_2$ dissociation:*

- _____
- _____
- _____
- _____
- _____

**Task 12.11.** *List the forms of $CO_2$ transport:*

- _____
- _____
- _____

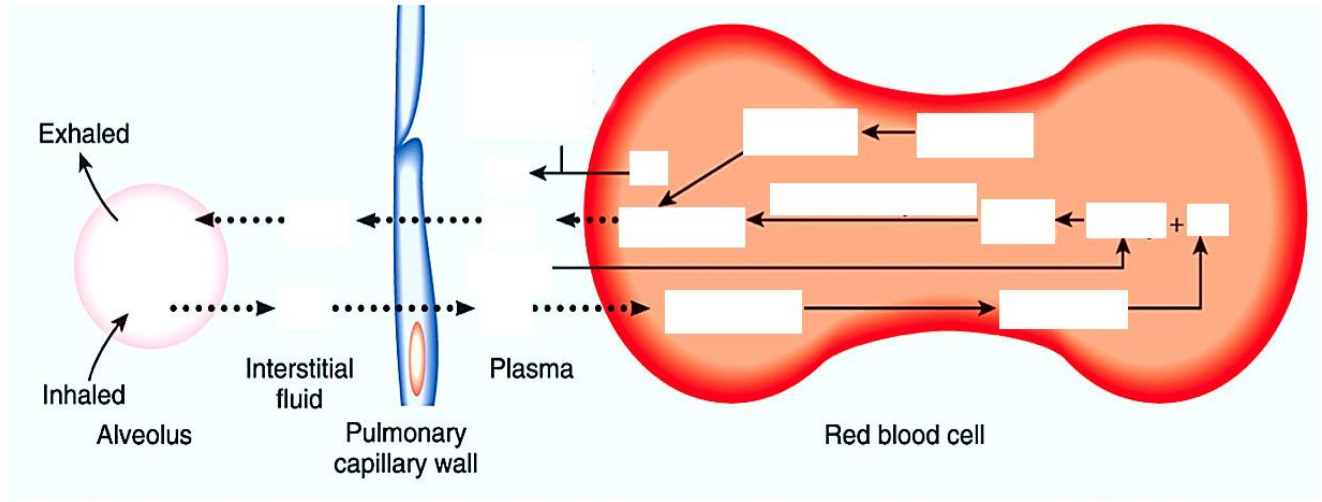
**Task 12.12. Dissolved $CO_2$**

- The solubility of $CO_2$ is 0.07 mL $CO_2$/100 mL blood/mm Hg;
- Calculate the concentration of dissolved $CO_2$ in 100 ml of arterial blood
- _____mL $CO_2$/100 mL blood
- which is approximately **5% of the total $CO_2$ content of blood**.

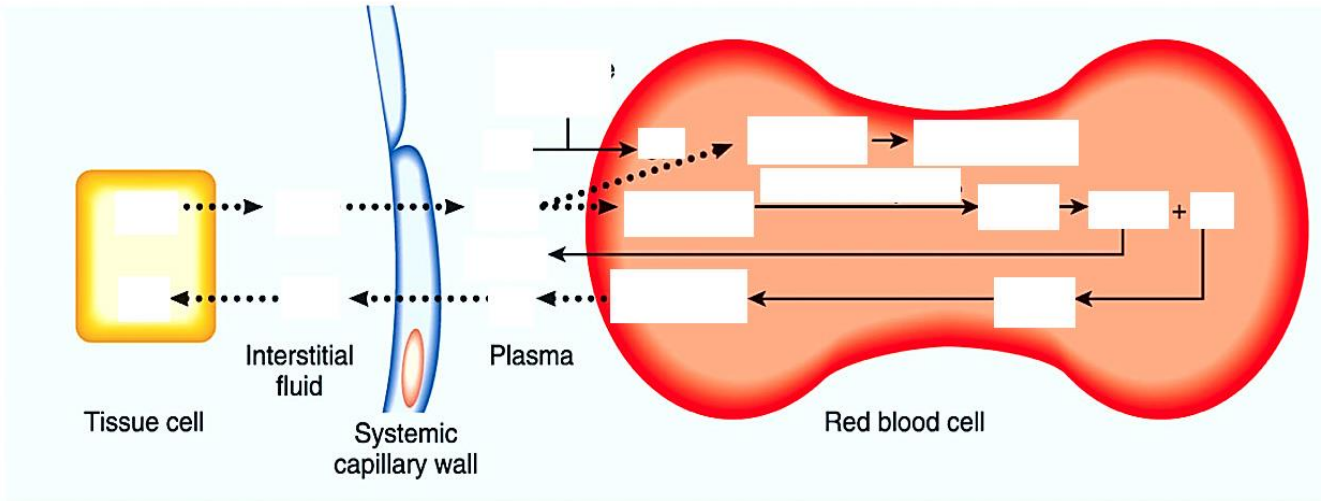
**Task 12.13.** *Carbaminohemoglobin and Bicarbonates*

- $CO_2$ is produced in tissues and binds to Hb, hemoglobin's affinity for $O_2$ is decreased and it releases $O_2$ to the tissues;
- release of $O_2$ from hemoglobin _____ its affinity for the $CO_2$ that is being produced in the tissues. (the **Haldane effect**).
- About _____% of the CO2 is carried as plasma bicarbonate.

**Task 12.14**. *The steps of gas exchange in a systemic and pulmonary capillary are following: (Fill the following illustrations)*




(a) Exchange of $O_2$ and $CO_2$ in pulmonary capillaries (external respiration)




(b) Exchange of $O_2$ and $CO_2$ in systemic capillaries (internal respiration)

**Task 12.15.** *Give the definitions of the following.*

***Oxygen utilization coefficient*** *is* _____

_____

*It can be calculated using following formula:*

——————— **x 100%**

**Task 12.16.** *Give the definition of ventilation-perfusion ratio.*

_____

_____

_____

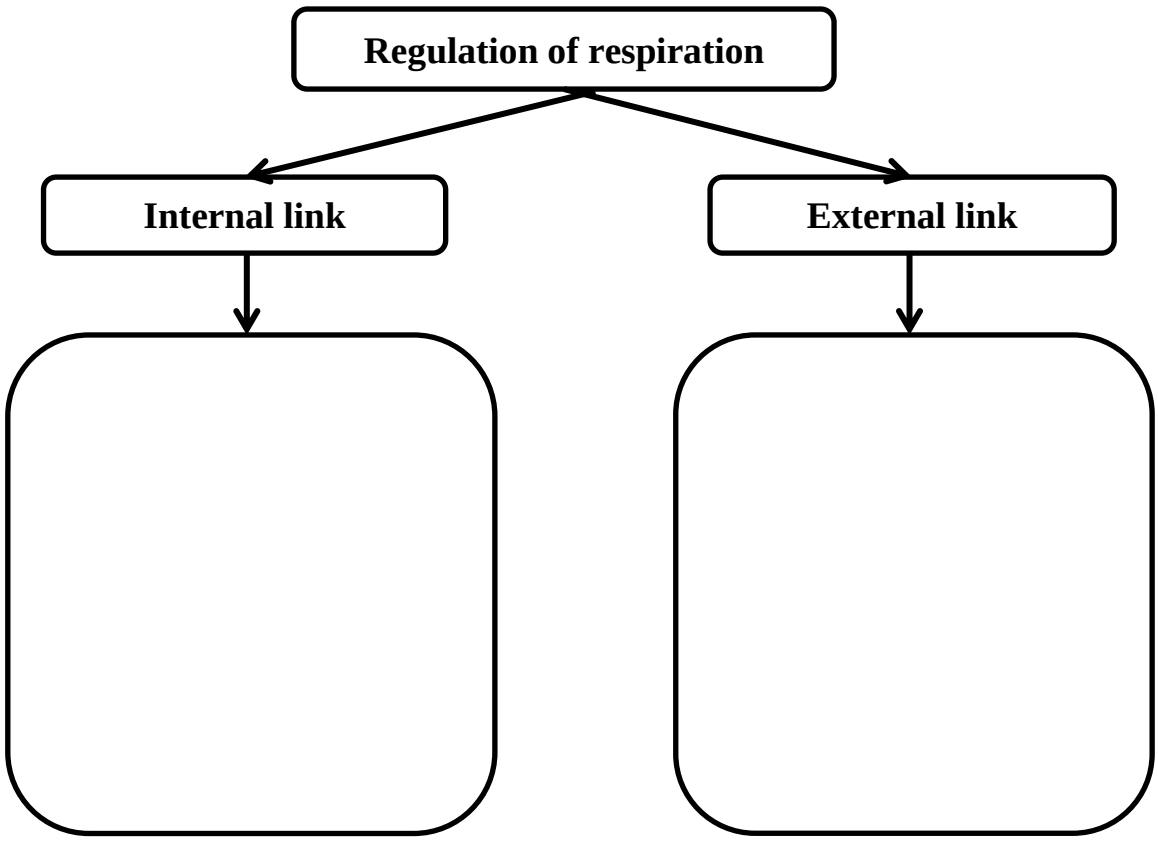
_____

**Task 12.17.** *Non-uniform ventilation-perfusion relationship in different areas of lungs can be explained by the following factors:*

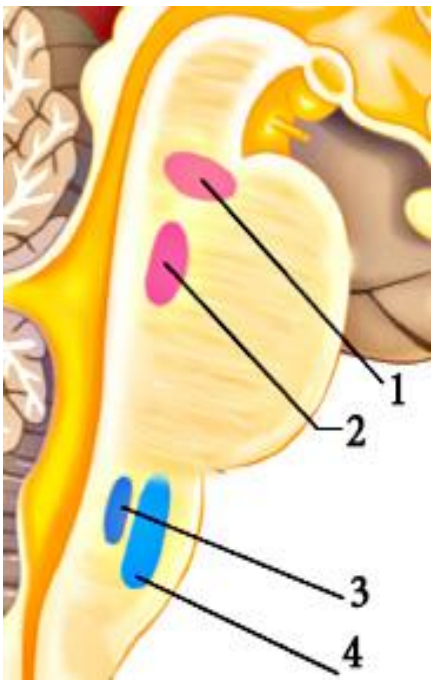
- _____
- _____
- _____
- _____

## 13. REGULATION OF RESPIRATION

**Task 13.1.** *Complete the table "Links of respiration regulation"*




**Task 13.2.** *Fill the scheme «Control respiratory centers of brainstem and their functions»*




| Name of center | Its function |
|---|---|
| 1. | |
| 2. | |
| 3. | |
| 4. | |
| 5. | |

**Task 13.3**. *Characterize central and peripheral chemoreceptors*

| **Peripheral chemoreceptors** | **Central chemoreceptors** |
|---|---|
| | |

**Task 13.4.** *Complete the table «Role of peripheral chemoreceptors in regulation of respiration»*

| Stimulation | Receptors | Afferent nerve | Center and effect | Efferent nerve | Organs-effectors | Response |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |

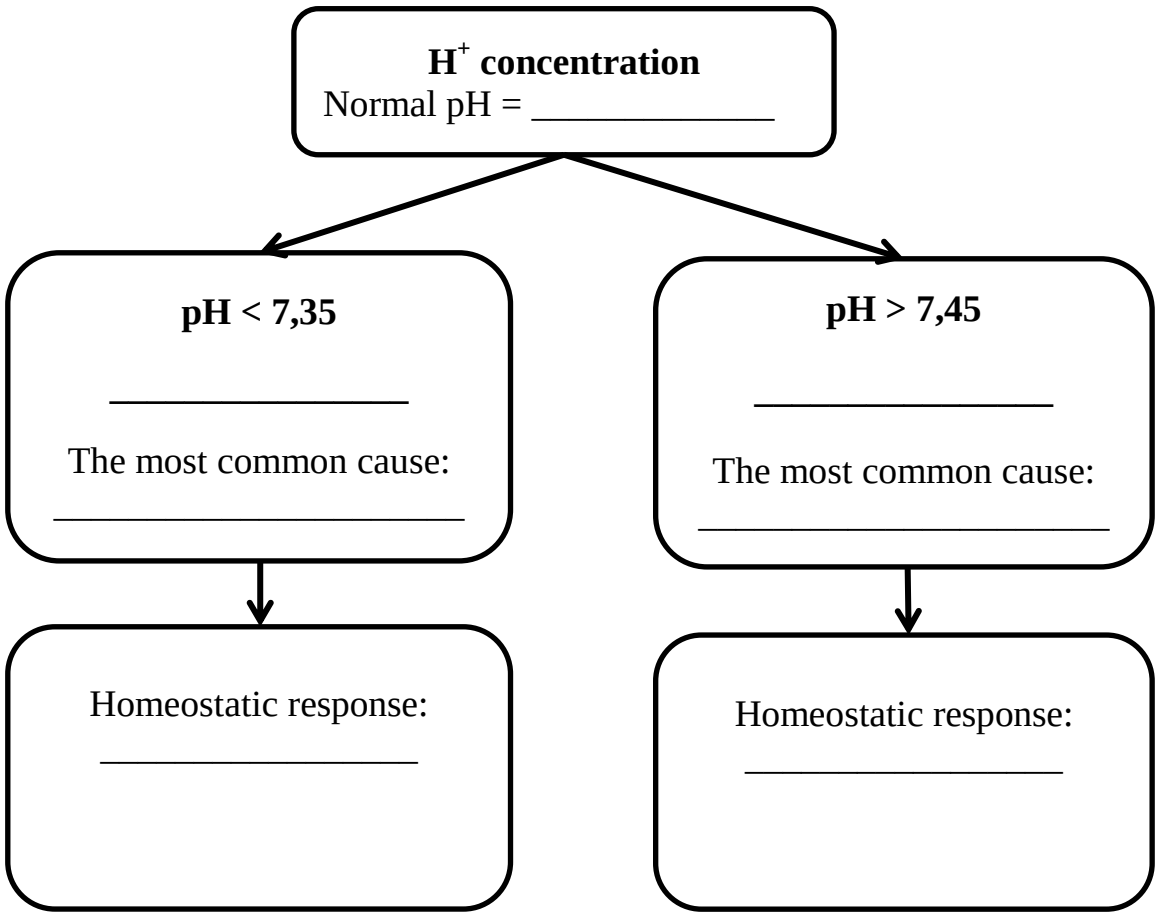
**Task 13.5.** *Complete the table «Hering-Breuer inflation reflex in regulation of respiration»*

| Stimulation | Receptors | Afferent nerve | Center and effect | Response |
|---|---|---|---|---|
| | | | | |

**Task 13.6.** *Complete the table «Role of other receptors in regulation of respiration»*

| Receptors | Effect on respiration |
|---|---|
| **Proprioreceptors** | |
| **Irritant receptors** | |
| **Juxtacapillary (J) receptors** | |
| **Receptors of pleura** | |
| **Olfactory receptors** | |
| **Apnoe reflex (diver reflex)** | |

**Task 13.7.** *Fill the scheme «Influence of hydrogen ions on respiration»*



**Task 13.8.** *Explain the role of cerebral cortex in regulation of respiration.*

_____

_____

_____

_____

_____

_____

**Task 13.9.** *Complete the table «Changes of respiration in case of brainstem, spinal cord and peripheral nerves transections on different levels»*

| Level of transection | Changes of breathing |
|---|---|
| **Above pons** | |
| **Below medulla** | |
| **Between pons and medulla** | |
| **Above $C_3$ of spinal cord** | |
| **Below $Th_6$ of spinal cord** | |
| **Between $C_5$ and $Th_1$ of spinal cord** | |
| **Transection of n. vagus** | |

**Task 13.10.** *Explain the respiratory components of following visceral reflexes.*
**Hiccup** _____

_____

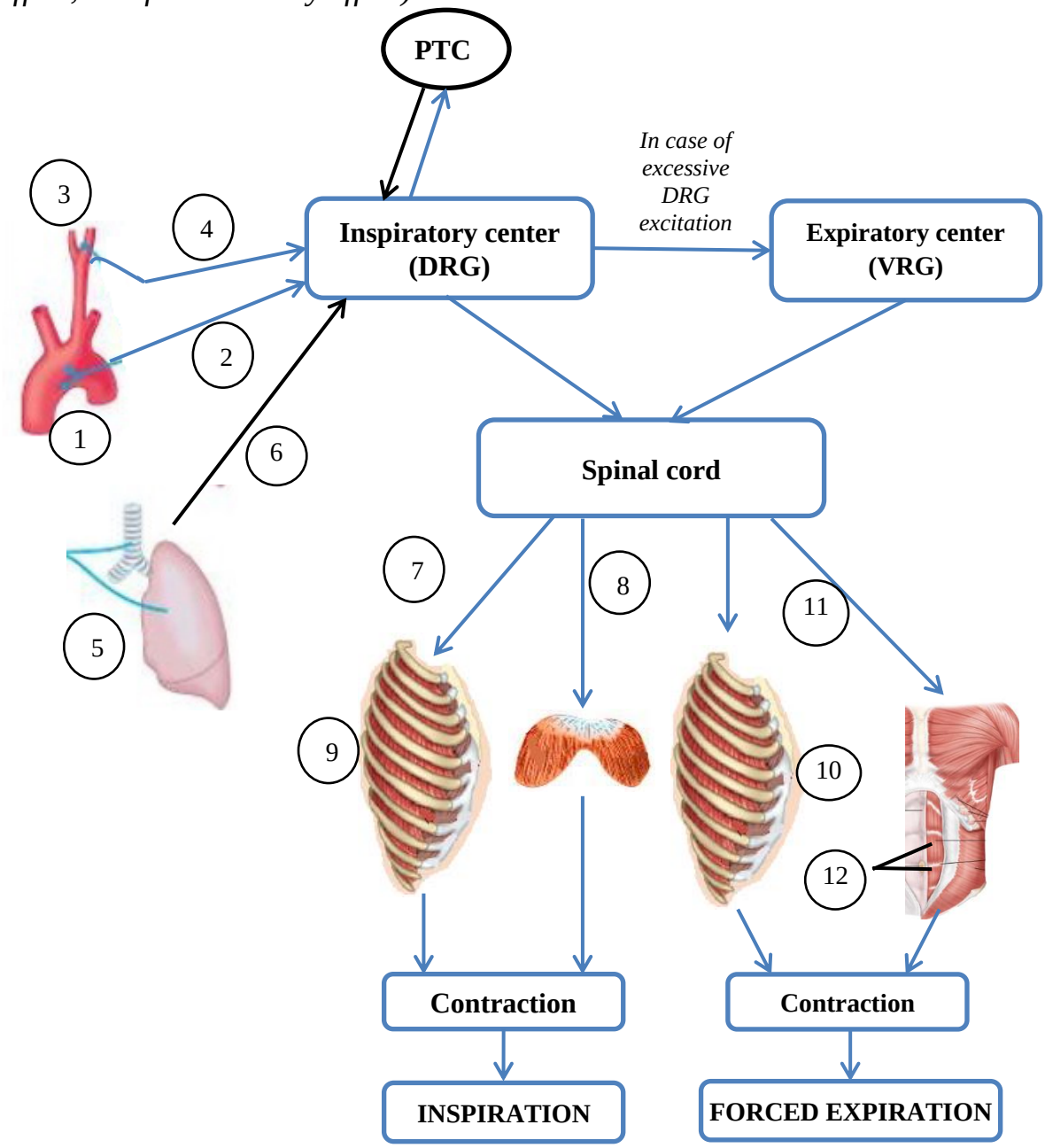
_____

**Yawning** _____

_____

_____

**Task 13.11.** *Label the picture «General scheme of respiration» ( put «+» for excitatory effect, «–» for inhibitory effect).*




| | |
|---|---|
| **1 –** | **7 –** |
| **2 –** | **8 –** |
| **3 –** | **9 –** |
| **4 –** | **10 –** |
| **5 –** | **11 –** |
| **6 –** | **12 –** |

**Task 13.12.** *Explain the effects of low barometric pressure on respiration.*

_____

_____

_____

_____

**Task 13.13.** *List the principal means of acclimatization to low $PO_2$.*

- _____
- _____
- _____
- _____

**Task 13.14.** *Explain the effects of high barometric pressure on respiration.*

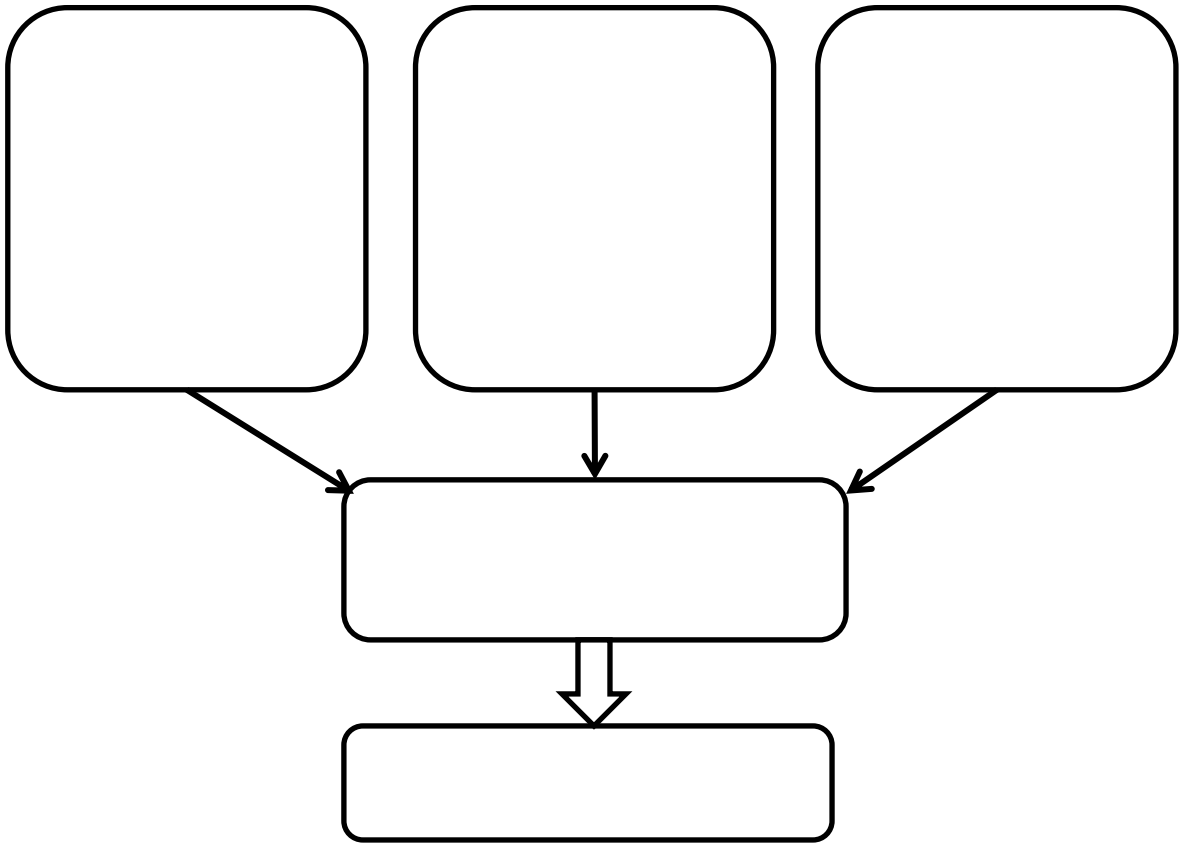
_____

_____

_____

_____

**Task 13.15.** *Fill the table "Mechanism of first breath in newborn"*



*Навчальне видання*

# Physiology of Visceral Systems «Blood, Circulation and Respiration»

## *Методичні вказівки для самостійної роботи студентів 2-го курсу з англомовною формою навчання*


Упорядники Чернобай Лариса Володимирівна
Маракушин Дмитро Ігоревич
Ісаєва Інна Миколаївна
Кармазіна Ірина Станіславівна
Алексеєнко Роман Васильович
Васильєва Оксана Василівна
Глоба Наталія Сергіївна
Булиніна Оксана Дмитрівна
Кириченко Михайло Петрович
Дунаєва Ольга Вікторівна
Гончарова Аліна Валеріївна
Шенгер Світлана Володимирівна



Відповідальний за випуск Л. В. Чернобай

Комп'ютерна верстка О. Ю. Лавриненко, О. О. Кучеренко

Формат А5. Ум. друк. арк. 4,77. Зам. № 20-33959.

---

**Редакційно-видавничий відділ**
**ХНМУ, пр. Науки, 4, м. Харків, 61022**
**izdatknmurio@gmail.com**

Свідоцтво про внесення суб'єкта видавничої справи до Державного реєстру видавництв, виготівників і розповсюджувачів видавничої продукції серії ДК № 3242 від 18.07.2008 р.